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F-18 CREW AUTOMATED ESCAPE SYSTEM AND ESCAPE SYSTEM REPLACEMENT PROGRAM

FINAL REPORT

Open entry

VOLUME I

CDRL ITEM #A005

Task Order No. 23

Contract N62269-78-C-0191

Prepared for

NAVAL AIR DEVELOPMENT CENTER

Warminster, Pennsylvania

October 1979

CSC

COMPUTER SCIENCES CORPORATION

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101 Masons Mill Business Park

Huntingdon Valley, Pennsylvania 19006

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SUMMARY

During the period of Task Order No. 23 (Contract N62269-78-C-0191). Computer Sciences Corporation (CSC) conducted 4 computer simulation studies for the Life Support Engineering Division (LSED) of the Naval Air Development Center (NADC). These studies were initiated at the request of Task Order 23 Cognizant Engineer, Mr. L. D'Aulerio, and were conducted using the ICARUS Aircrew Automated Escape System Simulation Model to simulate the performance of the F-14A, F-18A, and TF-18A ejection systems. The 4 studies that were completed are:

1. F-18A Ejection System Performance Study
2. F-18A controlled Angular Rate Study
3. F-14A Dual Mode Ejection Seat Study
4. TF-18A Ejection System Performance Study

Before conducting these studies, the ICARUS Program was modified to simplify the input file needed to run the program. While conducting the TF-18A Performance Study, several problems were found in the program. These problems were corrected and the modified program was validated by comparing the results of 8 Naval Weapons Center (NWC), China Lake, California F-18A sled tests with the results of 8 corresponding ICARUS simulation program runs.

In addition to these efforts, CSC implemented 3 utility programs in order to simplify the process of executing the ICARUS Program and the generation of output plots.

1.0 INTRODUCTION

This document describes the modifications made to ICARUS and the subsequent validation of the program, the 4 studies completed using the ICARUS Program, and the 3 utility programs implemented to simplify the process of making ICARUS runs and plots.

The problems encountered in the program, the modifications made to correct these problems and the program validation study are discussed in detail in Sections 3 and 4. Since the problems were discovered after the 4 studies had been completed, the discussion of these studies in Section 2 is limited to a brief description of the purpose of the study, the test runs made, a brief description of the results of the study, and the tables and/or plots requested by LSED for each test.

Section 5 contains instructions for using the 3 utility programs, along with a sample of the output generated by each.

2.0 STUDIES PERFORMED USING ICARUS

CSC conducted 4 studies for the LSED. These studies were conducted using the version of ICARUS that existed before the corrections described in Section 3.2 were made and the validation study described in Section 4 was conducted. Thus, the results of some of the runs made for the studies described in this section are questionable.

2.1 F-18A Escape System Performance Study

2.1.1 Purpose

At the request of the Cognizant Engineer (CE), CSC conducted an analysis of the F-18A Escape System. The purpose of the study was twofold:

1. The first objective was to validate the results generated by the ICARUS Program.
2. The second objective was to examine the performance of the F-18A escape system under various conditions at ejection.

2.1.2 Test Conditions

In order to achieve the first objective of the study, ICARUS was used to simulate 8 F-18A sled tests run at the Naval Weapons Center SNORT facility. The initial conditions for these 8 tests are listed in Table 2-1.

To meet the second objective, 22 tests were run. Figure 2-1, extracted from MIL-S-18471, lists for each test the required aircraft orientation at the time of ejection initiation.

TEST #	VELOCITY (KEAS)	PERCENTILE DUMMY
1	0	98
2	225	98
3	0	3
4	225	3
5	435	3
6	435	98
7	600	3
8	600	98

TABLE 2-1

TABLE I

ESCAPE SYSTEM IN-FLIGHT PERFORMANCE REQUIREMENT CAPABILITIES FOR ICAO STANDARD ATMOSPHERIC CONDITIONS

TERRAIN CLEARANCE Altitude (Feet) 1/			AIRCRAFT CONDITION AT ESCAPE SYSTEM INITIATION		
Single 7/ Place A/C		2/Two Place A/C	Altitude	Sink Rate (fpm)	Special KEAS 4/ 6/
1	22	40	Wings and nose level	2400	100
2	45	80	Wings and nose level	5000	100
3	20	30	30° bank and nose level	1200	50
4	25	45	30° bank and nose level	2000	50
5	30	55	30° bank and nose level	3000	100
6	45	85	30° bank and nose level	4500	100
7	20	40	45° bank and nose level	2000	100
8	124	157	45° bank and nose level	5000	100
9	201	214	90° bank and nose level	2000	100
10	320	353	90° bank and nose level	5000	100
11	245	245	120° bank and nose level	0	130
12	350	350	150° bank and nose level	0	130
13	384	384	180° bank and nose level	0	130
14	15	20	Wings level and 5° nose down	1200	130
15	20	30	Wings level and 10° nose down	2000	130
16	30	55	Wings level and 15° nose down	3000	130
17	45	85	Wings level and 20° nose down	4500	130
18	22	40	Wings and nose level	2400	350
19	22	40	Wings and nose level	2400	600 5/
20	570	722	Wings level, 30° nose down	3/	450
Ground level		Ground level	Wings level, 20° nose level	0	0
Ground level		Ground level	Wings level, 20° nose down	0	50

1/ Maximum acceptable altitude for initiation of safe escape based on the nominal time delays noted below. At no point in the trajectories shall the crewman equipped with applicable flight clothing, environmental protective garmets, and survival equipment contact the ground until the recovery parachute attains a steady state descent.

2/ Interseat delay time 0.4 sec, 0.30 sec canopy jettison delay.

3/ The aircraft descent rate attainable for the specified altitude and airspeed.

4/ All airspeeds measured along the aircraft flight path.

5/ The maximum aircraft airspeed if aircraft maximum airspeed is greater than 350 KEAS and less than 600 KEAS.

6/ Applicable at the instant the firing control is autamated.

Figure 2-1

2.1.3 Results

2.1.3.1 F-18A Track Tests

To verify the ICARUS Program, the results generated by ICARUS were compared against the actual test data obtained from the track tests. Figures A.1 to A.16 compare the trajectories generated by ICARUS with the trajectories measured at the track. Because the trajectory of the eighth test was observed to be very low, an effort was made to determine its cause. This effort consisted of varying several inputs to the ICARUS Program and then comparing the resultant trajectory with the low trajectory observed at the track. The following variables were modified, one at a time, to test their effect in lowering the simulated trajectory:

C.G. parameters

Tube parameters

Aerodynamic forces

Catapult thrust

Figures A.17 and A.18 compare the trajectory generated by the normal simulation with those generated by varying the C.G. parameters and the tube parameters; Figures A.19 and A.20 compare the trajectory generated by the normal simulation with those generated by varying the aerodynamic forces and the catapult thrust.

2.1.3.2 F-18A Performance Tests

In addition to listing the aircraft conditions at the time of ejection initiation for the 22 performance tests, MIL-S-18471 states that the

occupant must obtain a steady state of descent rate equal to, or less than, 30 fps total velocity with a vertical component no greater than 24 fps.

Figure 2-2 displays the aircraft orientation at the time of the escape system initiation and the following corresponding occupant trajectory data generated by the simulation model for each test:

1. The maximum altitude obtained during the interval from rocket burnout to recovery chute full inflation or occupant impact (whichever comes first).
2. The altitude, vertical and total velocity at full inflation or impact.
3. The value of the computed performance indices.

Due to the fact that the recovery chute simulation implemented in ICARUS at the time this study was conducted had been developed for a chute other than the one employed in the F-18A aircraft, it was decided to use the vertical and total velocity of the crewperson at either full inflation or impact (whichever came first) in determining whether or not the test ejection was predicted as being successful, marginal or a failure.

An empirical index was developed to aid in this determination. This index (PI-performance index) was derived as a function of the total velocity and altitude at impact or full inflation and the maximum allowable total velocity (30 feet/sec).

PERFORMANCE TESTS - SUCCESS/FAILURE ANALYSIS DATA

Test Number	Initial Altitude (Ft)	Initial Speed (Knots)	Initial Pitch (Deg)	Initial Roll (Deg)	Initial Sink Rate (Ft/Sec)	Max. Alt. After Roc. B.O. (Ft)	Alt. At Full Infl. (Ft)	Ver. Vel. At Full Infl. (Ft/Sec)	Tot. Vel. At Full Infl. (Ft/Sec)	Ver. Vel. At Impact (Ft/Sec)	Tot. Vel. At Impact (Ft/Sec)	Performance Index (PI)
1	22	100	0	0	40	82.1	76.4	13.7	89.4	-	-	.22
2	45	100	0	0	83.33	18.7	-	-	-	38.2	136.3	4.54
3	20	50	0	30	20	136.9	114.8	39.4	50.4	-	-	.03
4	25	50	0	30	33.33	92.3	76.2	29.4	64.0	-	-	.16
5	30	100	0	30	50	58.6	12.9	35.3	51.3	-	-	1.10
6	45	100	0	30	74	24	-	-	-	36.3	132.4	4.41
7	20	100	0	45	33.33	62.3	56.3	27.2	95.5	-	-	.47
8	124	100	0	45	83.33	82.3	23.4	53.3	77.2	-	-	1.16
9	201	100	0	90	33.33	166.4	-	-	-	62.6	114.4	3.81
10	320	100	0	90	83.33	277.9	103.6	71.6	115.7	-	-	.11
11	245	130	0	120	0	217.4	60.9	66.5	138.5	-	-	.58
12	350	130	0	150	0	304.6	-	-	-	126.0	189.2	6.31
13	384	130	0	180	0	334.0	41.1	104.4	140.2	-	-	1.23
14	15	130	-5	0	20	123.1	98.4	37.9	79.8	-	-	.09
15	20	130	-10	0	33.33	91.1	50.9	45.1	60.8	-	-	.48
16	30	130	-15	0	50	54.4	11.4	37.8	56.6	-	-	1.28
17	45	130	-20	0	75	20.3	-	-	-	34.2	192.6	6.42
18	22	350	0	0	40	80.8	29.9	48.9	96.9	-	-	1.17
19	22	600	0	0	40	45.2	42.5	10.4	223.6	-	-	1.76
20	570	450	-30	0	75	526.6	461.0	77.0	191.2	-	-	0
21	0	0	-20	0	0	137.8	105.0	30.9	44.5	-	-	.04
22	0	50	-20	0	0	134.9	115.8	28.0	58.1	-	-	.04

Figure 2-2

The index was computed as follows:

$$PI = \frac{Vel_t}{\left(Vel_{tmax}\right) p} \quad \text{where:} \quad p = 1 + \frac{Alt}{c}$$

where: Vel_t is defined as the total velocity obtained by the crewperson at the time of recovery chute full inflation or impact (feet/sec).

Vel_{tmax} is defined as the total maximum velocity allowed at impact (30 feet/sec).

Alt is defined as the altitude at inflation, 0 at impact, (feet).

c is an empirically derived constant - the value used for this study being 100 (feet).

The following subjective intervals, based on past experience in the use of the model and historical trajectory sled test data, were used to determine whether the generated simulated trajectory obtained was successful, marginal, or a failure:

Success: $0 \leq PI \leq 1$

Marginal: $1 < PI \leq 2$

Failure: $2 < PI$

Based upon these intervals and the associated Performance Index computed for each case, a success, marginal and failure table (Figure 2-3) was derived indicating whether each test case simulated was considered successful, marginal or a failure.

TEST NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Success	X		X	X			X			X	X			X	X					X	X	X
Marginal					X			X					X			X		X	X			
Failure		X				X			X			X					X					

Figure 2-3 - Success, Marginal, Failure Test Case

(Note: Caution should be exercised in using the Performance Index defined above, for cases other than those shown in Figure 2-3. The Performance Index was designed specifically for this study and is not all encompassing, as illustrated by the following example:

Given a total velocity of 60 ft/sec at impact,

$$PI = \frac{60}{30} = 2$$

This defines the test as marginal, whereas MIL-S-18471 requirements define this test as a failure.)

Figures A.21 through A.42 in Appendix A show the trajectories generated by ICARUS for these 22 tests.

Since tests 2, 6, 9, 12 and 17 were designated as failures, the CE requested that they be rerun to determine the minimum altitude required at ejection (all other test conditions being the same) to escape safely. Table 2-2 shows the altitude specified in MIL-S-18471 and the minimum altitude requirements as determined by ICARUS for these 5 tests.

2.2 F-18A Controlled Angular Rate Study

2.2.1 Purpose

At the request of the CE, CSC conducted a study to determine the difference in performance that would be effected by having an ejection seat remain upright and facing the relative wind at all times. In order to force the seat to remain upright and facing the relative wind throughout the ejection, ICARUS was modified so that the angular accelerations would always be zero.

TEST #	ALTITUDE SPECIFIED IN MIL-S-18471 (Ft)	MINIMUM ALLOWED ALTITUDE FOR SAFE EJECTION (Ft)
2	45	65
6	45	65
9	201	250
12	350	400
17	45	70

Table 2-2

2.2.2 Test Conditions

Four runs were made to complete this study - 2 normal ejections and 2 controlled ejections. The test conditions for the 4 runs made are shown in Table 2-3.

2.2.3 Results

To compare the results of the normal ejections with the controlled ejections, the altitude vs. downrange trajectory and the total velocity vs. time were plotted. Figure B.1 in Appendix B shows the results for the 400 knot test; Figure B-2 in Appendix B shows the results for the 600 knot test.

2.3 F-14A Dual Mode Ejection Seat Study

2.3.1 Purpose

The dual mode ejection seat was proposed as a way to solve the problems of adverse attitude ejections. In this system, a sensor would detect the adverse condition (for example, an inverted attitude) and activate a mechanism which would prevent the booster rocket from igniting. This would prevent the seat from being propelled into the ground and enhance the escape envelope of a given system.

To prove the feasibility of the Dual Mode Ejection Seat, two tests were conducted using an F-14A GRU-7 Ejection Seat. The purpose of this study was to use ICARUS to simulate these two tests, and run 4 additional tests.

TEST #	VELOCITY (KEAS)	PERCENTILE OCCUPANT	ALTITUDE (FT)	PITCH (DEG)	ROLL (DEG)	NORMAL/ CONTROLLED
1	400	98	0	0	0	N
1-a	400	98	0	0	0	C
2	600	98	0	0	0	N
2-a	600	98	0	0	0	C

Table 2-3

2.3.2 Test Conditions

Table 2-4 shows the conditions which were run to simulate the actual tests conducted of the Dual Mode Ejection System; Table 2-5 shows the additional test conditions that were run, as specified by NADC.

2.3.3 Results

Trajectory plots were made for each test run. Figures C.1 and C.2 in Appendix C compare the trajectories generated by ICARUS for tests 1 and 1(a); Figures C.3 and C.4 compare the trajectories generated by ICARUS for tests 2 and 2(a); Figures C-5, C-6, C-7, C-8 show the trajectories generated by ICARUS for tests 3, 3(a), 4, 4(a) respectively.

2.4 TF-18A Escape System Performance Study

2.4.1 Purpose

At the request of the CE, CSC conducted a performance study of the TF-18A Escape System. The objective of this study was to determine an optimum time delay between the front and rear seat ejections to:

1. Allow sufficient time to avoid rocket blast damage.
2. Allow sufficient spatial separation between the 2 seat/occupant systems to avoid collision and entanglement of parachute lines.

2.4.2 Test Conditions

CSC and NADC personnel jointly defined 29 test conditions which were run initially. These can be considered in 3 groups as shown in Table 2-6.

Test #	Altitude (Ft)	Velocity (Ft/Sec) Vx	Vy	Vz	Wind Knots at Deg.	Temperature (°Celsius)	Atmos. Press. (Millibars)	Atmos. Dens. (Grms/CU Meter)	Weight (lbs.)	Rocket Motor
1	5300	-315	441	55	8 at 84	13.1	848.9	1027.5	450	Off
1(a)	5300	-315	441	0	8 at 84	13.1	848.9	1027.5	450	Off
2	5000	-314	425	-29	4 at 324	23.3	851.2	996.8	448	On
2(a)	5000	-314	425	0	4 at 324	23.3	851.2	996.8	448	On

Table 2-4

Test #	Altitude (Ft)	Velocity (Ft/Sec) Vx	Vy	Vz	Wind Knots at Deg.		Temp. (° Cel.)	Atmos. Pressure (Millibars)	Atmos. Density (Grms./Cu. Meter)	Weight (lbs.)	Pitch (Deg.)	Cat. Ig. Time (Sec.)	Drogue Fire Time (Sec.)	Drogue Open Time (Sec.)	Shackle Release Time (Sec.)	Line Stretch Time (Sec.)	Full Inflation Time (Sec.)	Rocket Motor
3	5298.5	299.6	454.6	47.1	8	84	13.1	848.9	1027.5	450	0	0	.517	.838	1.936	2.336	3.815	Off
3(a)	5298.5	299.6	454.6	0.0	8	84	13.1	848.9	1027.5	450	15	0	.517	.838	1.936	2.336	3.815	Off
4	5012	314.3	429.6	-25.0	4	324	23.3	851.2	996.8	448	0	0	.517	.838	1.936	2.336	3.815	On
4(a)	5012	314.3	429.6	0.0	4	324	23.3	851.2	996.8	448	15	0	.517	.838	1.936	2.336	3.815	On

Table 2-5

TF-18A EJECTION SYSTEM PERFORMANCE STUDY PART 1
TEST CONDITIONS

Test #	Altitude (Ft)	Velocity (KEAS)	Sink Rate Ft/Sec	Pitch (Deg)	Roll (Deg)	Percentile Dummy F	Percentile Dummy R	Time Delay (Sec)	Direction at Divergence F	Direction at Divergence R
1-1	0	0	0	0	0	3	98	.4	Right	Left
1-2	0	200	0	0	0	3	98	.4	Right	Left
1-3	0	500	0	0	0	3	98	.4	Right	Left
1-4	214	100	33.33	0	90	3	98	.4	Right	Left
1-5	40	600	40	0	0	3	98	.4	Right	Left
1-6	40	100	33.33	0	45	3	98	.4	Right	Left
1-7	245	130	0	0	120	3	98	.4	Right	Left
1-8	384	130	0	0	180	3	98	.4	Right	Left
1-9	55	130	50	-15	0	3	98	.4	Right	Left
1-10	20	130	20	-5	0	3	98	.4	Right	Left
1-11	0	0	0	0	0	3	98	.2	Right	Left
1-12	0	200	0	0	0	3	98	.2	Right	Left
1-13	0	500	0	0	0	3	98	.2	Right	Left
1-14	214	100	33.33	0	90	3	98	.2	Right	Left
1-15	40	600	40	0	0	3	98	.2	Right	Left
1-16	40	100	33.33	0	45	3	98	.2	Right	Left
1-17	245	130	0	0	120	3	98	.2	Right	Left
1-18	384	130	0	0	180	3	98	.2	Right	Left
1-19	55	130	50	-15	0	3	98	.2	Right	Left
1-20	20	130	20	-5	0	3	98	.2	Right	Left
1-21	0	0	0	0	0	98	3	.4	Right	Left
1-22	0	0	0	0	0	98	98	.4	Right	Left
1-23	0	0	0	0	0	3	3	.4	Right	Left
1-24	0	200	0	0	0	98	3	.4	Right	Left
1-25	0	200	0	0	0	98	98	.4	Right	Left
1-26	0	200	0	0	0	3	3	.4	Right	Left
1-27	0	500	0	0	0	98	3	.4	Right	Left
1-28	0	500	0	0	0	98	98	.4	Right	Left
1-29	0	500	0	0	0	3	3	.4	Right	Left

Table 2-6

The first group of cases (tests 1.1-1.10) tests various initial conditions using a .4 second time delay between front and rear seat ejections. Tests 1.1-1.3 represent low speed (0 knot), medium speed (200 knot) and high speed (500 knot) sled test type runs. Tests 1.4-1.10 were chosen as a representative sample of the 22 Escape System In Flight Performance Requirements Capabilities Tests (see Figure 2-1).

The second group of cases (tests 1.11-1.20) tests the same initial conditions as tests 1.1-1.10, but uses a .2 second time delay between front and rear seat ejections.

The third group of cases (tests 1.21-1.29) tests all of the possible combinations of 3 percentile and 98 percentile occupants, in the front and rear seats, for the 3 sled test type runs defined above. These were run using a .4 second time delay between front and rear seat ejections.

All runs made for the TF-18A Ejection System Performance Study were made to recovery chute full inflation (unless impact occurred first).

When this series of runs was completed, NADC requested that a series of runs be made to determine what effect having the seats diverge in opposite directions has in avoiding a collision. Table 2-7 shows the test conditions which were run.

NADC also requested that the predicted trajectories and spatial separation between the front and rear seat/occupant/occupant alone systems be plotted for the 2 test cases shown in Table 2-8.

TF-18A EJECTION SYSTEM PERFORMANCE STUDY - PART 2
TEST CONDITIONS

Test #	Altitude (Ft)	Velocity (KEAS)	Sink Rate (Ft/Sec)	Pitch (Deg)	Roll (Deg)	Percentile Occ. F	Percentile Occ. R	Time Delay (Sec)	Direction of Divergence F	Direction of Divergence R
2.1-a	0	0	0	0	0	3	98	.4	Right	Left
2.1-b	0	0	0	0	0	3	98	.4	Left	Left
2.2-a	0	0	0	0	0	98	3	.4	Right	Left
2.2-b	0	0	0	0	0	98	3	.4	Left	Left
2.3-a	0	0	0	0	0	98	98	.4	Right	Left
2.3-b	0	0	0	0	0	98	98	.4	Left	Left
2.4-a	0	0	0	0	0	3	3	.4	Right	Left
2.4-b	0	0	0	0	0	3	3	.4	Left	Left
2.5-a	0	100	0	0	0	3	98	.4	Right	Left
2.5-b	0	100	0	0	0	3	98	.4	Left	Left
2.6-a	0	150	0	0	0	3	98	.4	Right	Left
2.6-b	0	150	0	0	0	3	98	.4	Left	Left
2.7-a	0	200	0	0	0	3	98	.4	Right	Left
2.7-b	0	200	0	0	0	3	98	.4	Left	Left
2.8-a	0	200	0	0	0	98	3	.4	Right	Left
2.8-b	0	200	0	0	0	98	3	.4	Left	Left
2.9-a	0	200	0	0	0	98	98	.4	Right	Left
2.9-b	0	200	0	0	0	98	98	.4	Left	Left
2.10-a	0	200	0	0	0	3	3	.4	Right	Left
2.10-b	0	200	0	0	0	3	3	.4	Left	Left
2.11-a	0	250	0	0	0	3	98	.4	Right	Left
2.11-b	0	250	0	0	0	3	98	.4	Left	Left
2.12-a	0	300	0	0	0	3	98	.4	Right	Left
2.12-b	0	300	0	0	0	3	98	.4	Left	Left
2.13-a	0	350	0	0	0	3	98	.4	Right	Left
2.13-b	0	350	0	0	0	3	98	.4	Left	Left
2.14-a	0	400	0	0	0	3	98	.4	Right	Left
2.14-b	0	400	0	0	0	3	98	.4	Left	Left
2.15-a	0	500	0	0	0	3	98	.4	Right	Left
2.15-b	0	500	0	0	0	3	98	.4	Left	Left
2.16-a	0	500	0	0	0	98	3	.4	Right	Left
2.16-b	0	500	0	0	0	98	3	.4	Left	Left
2.17-a	0	500	0	0	0	98	98	.4	Right	Left
2.17-b	0	500	0	0	0	98	98	.4	Left	Left
2.18-a	0	500	0	0	0	3	3	.4	Right	Left
2.18-b	0	500	0	0	0	3	3	.4	Left	Left

Table 2-7

TF-18A PERFORMANCE STUDY - PART 3
TEST CONDITIONS

Test #	Altitude (Ft)	Velocity (KEAS)	Sink Rate (Ft/Sec)	Pitch (Deg)	Roll (Deg)	Percentile Occ.		Time Delay (Sec)	Direction of Divergence	
						F	R		F	R
3.1	0	0	0	-30	-30	3	98	.4	Right	Left
3.2	0	0	0	-30	30	3	98	.4	Right	Left

Table 2-8

To complete the TF-18A Escape System Performance Study, NADC requested that the tests shown in Table 2-9 be run and the predicted trajectories plotted.

2.4.3 Results

The possibility of collision between the front and rear seat/occupant/occupant alone systems was examined for the tests shown in Tables 2-6 and 2-7. The possibility of collision between the rear seat and the front seat/occupant/occupant alone system after rear seat/occupant separation, and between the front seat and the rear seat/occupant/occupant alone system after front seat/occupant separation was examined only for the tests in Table 2-6.

To determine whether a collision would occur, each ejection was divided into 3 stages and a separation envelope was defined around the seat/occupant system for each stage. The separation envelope was defined as a sphere whose center is the C.G. of the seat/occupant system and whose radius is defined by the stage of the ejection. During the ROCKET stage, from CATAPULT IGNITION to DROGUE PROJECTION, the radius of the sphere was 5 ft; during the DROGUE stage, from DROGUE PROJECTION to RECOVERY CHUTE CONTAINER OPEN, the radius of the sphere was 14.5 ft. (the length of the drogue chute suspension lines); during the RECOVERY stage, from RECOVERY CHUTE CONTAINER OPEN to RECOVERY CHUTE FULL INFLATION, the radius of the sphere was 22.75 ft. (the length of the recovery chute suspension lines). The possibility of collision/entanglement was acknowledged if the safety envelopes of the two seats

TF-18A EJECTION SYSTEM PERFORMANCE STUDY - PART 4
TEST CONDITIONS

Test #	Altitude (Ft)	Velocity (KEAS)	Sink Rate (Ft/Sec)	Pitch (Deg)	Roll (Deg)	Percentile Occ. F	Percentile Occ. R	Time Delay (Sec)	Direction of Divergence F	Direction of Divergence R
4.1	0	0	0	-10	20	3	98	.4	Right	Left
4.2	0	100	0	0	0	3	98	.4	Right	Left
4.3	0	150	0	0	0	3	98	.4	Right	Left
4.4	0	225	0	0	0	98	3	.4	Right	Left
4.5	0	435	0	0	0	98	3	.4	Right	Left
4.6	0	600	0	0	0	3	98	.4	Right	Left

Table 2-9

intersected at any time. If the spatial separation between the 2 systems was within $\pm$ 10% of the defined safety envelope, the test was defined as marginal; if the spatial separation between the 2 systems was more than the defined envelope + 10%, the test was defined as successful; if the spatial separation between the 2 systems was less than the defined envelope - 10%, the test was defined as a failure. For the initial test conditions in Table 2-6, there were no collision or entanglement problems found when a .4 second time delay was used between seat ejections (tests 1.1 through 1.10 and tests 1.21 through 1.29.) When this time delay was reduced to .2 seconds, a collision problem occurred in each of the test cases (tests 1.11 through 1.20). Tables 2-10 through 2-19 show the spatial separation data for the 2 seat/occupant/occupant alone systems for these 10 tests. An analysis of the spatial separation between the rear seat and front seat/occupant/occupant alone and between the front seat and the rear occupant, indicated that there were no collision problems in any of tests 1.1 through 1.29.

Of the 18 conditions run to test what effect having the seats diverge in opposite directions has in avoiding a collision, tests 2.1, 2.3, 2.4, 2.5, 2.6, and 2.7 were successful when the seats diverged in opposite directions, but showed collision/entanglement problems when the seats diverged in the same direction. Tables 2-20 through 2-25 show the spatial separation data for these 6 tests.

Trajectory plots and plots showing the spatial separation between the front and rear seat/occupant/occupant alone systems were generated for

TF-18A PERFORMANCE STUDY - TEST 1.11 .2 SECOND DELAY

REAR SEAT: 98 Percentile FRONT SEAT: 3 Percentile VELOCITY: 0 Knots

ALTITUDE: 0 Ft. SINK RATE: 0 Ft/Sec. PITCH: 0 Degrees ROLL: 0 Degrees

Time	Spatial Sep. (Ft)	Combined Safety Envelope (Ft)	Status	Stage Front Occ.	Stage Rear Occ.
.500	8.0476	10.00	F	Rocket	Drogue
.522	9.0080	10.00	M	Rocket	Drogue
.565	10.9723	10.00	M	Rocket	Drogue
.800	17.5158	19.50	F	Rocket	Drogue
.812	17.5508	19.50	M	Rocket	Drogue
.836	17.5511	19.50	M	Rocket	Drogue
.837	17.5496	19.50	F	Rocket	Drogue
.880	17.4443	19.50	F	Rocket	Drogue
.900	17.5128	19.50	F	Rocket	Drogue
.904	17.5433	19.50	F	Rocket	Drogue
.905	17.5519	19.50	M	Rocket	Drogue
1.000	20.6148	29.00	F	Drogue	Drogue
1.010	21.1261	29.00	F	Drogue	Drogue
1.080	25.7417	29.00	F	Drogue	Drogue
1.090	26.4951	29.00	M	Drogue	Drogue
1.150	31.5559	29.00	M	Drogue	Drogue

Table 2-10

TF-18A PERFORMANCE STUDY - TEST 1.12 .2 SECOND DELAY

REAR SEAT: 98 Percentile FRONT SEAT: 3 Percentile VELOCITY: 200 Knots

ALTITUDE: 0 Ft. SINK RATE: 0 Ft/Sec. PITCH: 0 Degrees ROLL: 0 Degrees

Time	Spatial Sep. (Ft)	Combined Safety Envelope (Ft)	Status	Stage Front Occ.	Stage Rear Occ.
.500	8.0642	10.00	F	Rocket	Rocket
.521	8.9755	10.00	F	Rocket	Rocket
.522	9.0194	10.00	M	Rocket	Rocket
.565	10.9961	10.00	M	Rocket	Rocket
.800	18.2356	19.50	M	Rocket	Drogue
.840	18.3646	19.50	M	Rocket	Drogue
.875	18.3390	19.50	M	Rocket	Drogue
.900	18.4119	19.50	M	Rocket	Drogue
.999	21.2450	19.50	M	Rocket	Drogue
1.000	21.2897	29.00	F	Drogue	Drogue
1.080	25.8524	29.00	F	Drogue	Drogue
1.090	26.5043	29.00	M	Drogue	Drogue
1.100	27.1642	29.00	M	Drogue	Drogue
1.160	31.3508	29.00	M	Drogue	Drogue

Table 2-11

TF-18A PERFORMANCE STUDY - TEST 1.13 .2 SECOND DELAY

REAR SEAT: 98 Percentile FRONT SEAT: 3 Percentile VELOCITY: 500 Knots

ALTITUDE: 0 Ft. SINK RATE: 0 Ft/Sec. PITCH: 0 Degrees ROLL: 0 Degrees

Time	Spatial Sep. (Ft)	Combined Safety Envelope (Ft)	Status	Stage Front Occ.	Stage Rear Occ.
.500	7.9551	10.00	F	Rocket	Rocket
.525	8.9978	10.00	F	Rocket	Rocket
.526	9.0392	10.00	M	Rocket	Rocket
.569	10.9860	10.00	M	Rocket	Rocket

Table 2-12

TF-18A PERFORMANCE STUDY - TEST 1.14 .2 SECOND DELAY

REAR SEAT: 98 Percentile FRONT SEAT: 3 Percentile VELOCITY: 100 Knots

ALTITUDE: 214 Ft. SINK RATE: 33.33 Ft/Sec PITCH: 0 Degrees ROLL: 90 Degrees

Time	Spatial Sep. (Ft)	Combined Safety Envelope (Ft)	Status	Stage Front Occ.	Stage Rear Occ.
.500	7.9751	10.00	F	Rocket	Rocket
.523	8.9602	10.00	F	Rocket	Rocket
.524	9.0034	10.00	M	Rocket	Rocket
.568	10.9794	10.00	M	Rocket	Rocket
.800	17.6458	19.50	M	Rocket	Drogue
.840	17.7486	19.50	M	Rocket	Drogue
.868	17.7303	19.50	M	Rocket	Drogue
.900	17.8424	29.00	M	Rocket	Drogue
.999	21.1376	29.00	M	Rocket	Drogue
1.000	21.1880	29.00	F	Drogue	Drogue
1.076	26.0821	29.00	F	Drogue	Drogue
1.077	26.1567	29.00	M	Drogue	Drogue
1.100	27.9058	29.00	M	Drogue	Drogue
1.145	31.8126	29.00	M	Drogue	Drogue

Table 2-13

TF-18A PERFORMANCE STUDY - TEST 1.15 .2 SECOND DELAY

REAR SEAT: 98 Percentile FRONT SEAT: 3 Percentile VELOCITY: 600 Knots

ALTITUDE: 40 Ft. SINK RATE: 40 Ft/Sec PITCH: 0 Degrees ROLL: 0 Degrees

Time	Spatial Sep. (Ft)	Combined Safety Envelope (Ft)	Status	Stage	
				Front Occ.	Rear Occ.
.500	8.5190	10.00	F	Rocket	Rocket
.510	8.9960	10.00	F	Rocket	Rocket
.511	9.0446	10.00	M	Rocket	Rocket
.547	10.9795	10.00	M	Rocket	Rocket

Table 2-14

TF-18A PERFORMANCE STUDY - TEST 1.16 .2 SECOND DELAY

REAR SEAT: 98 Percentile FRONT SEAT: 3 Percentile VELOCITY: 100 Knots

ALTITUDE: 40 Ft. SINK RATE: 33.33 Ft/Sec PITCH: 0 Degrees ROLL: 45 Degrees

Time	Spatial Sep. (Ft)	Combined Safety Envelope (Ft)	Status	Stage Front Occ.	Stage Rear Occ.
.500	8.0791	10.00	F	Rocket	Rocket
.520	8.9559	10.00	F	Rocket	Rocket
.521	9.0004	10.00	M	Rocket	Rocket
.564	10.9882	10.00	M	Rocket	Rocket
.800	17.9380	19.50	M	Rocket	Drogue
.834	18.0226	19.50	M	Rocket	Drogue
.874	17.9764	19.50	M	Rocket	Drogue
.900	18.0682	19.50	M	Rocket	Drogue
.999	21.1875	19.50	M	Rocket	Drogue
1.000	21.2360	29.00	F	Drogue	Drogue
1.077	26.0902	29.00	F	Drogue	Drogue
1.078	26.1631	29.00	M	Drogue	Drogue
1.100	27.8029	29.00	M	Drogue	Drogue
1.148	31.8744	29.00	M	Drogue	Drogue

Table 2-15

TF-18A PERFORMANCE STUDY - TEST 1.17 .2 SECOND DELAY

REAR SEAT: 98 Percentile FRONT SEAT: 3 Percentile VELOCITY: 130 Knots

ALTITUDE: 245 Ft. SINK RATE: 0 Ft/Sec PITCH: 0 Degrees ROLL: 120 Degrees

Time	Spatial Sep. (Ft)	Combined Safety Envelope (Ft)	Status	Stage Front Occ.	Stage Rear Occ.
.500	7.9790	10.00	F	Rocket	Rocket
.523	8.9632	10.00	F	Rocket	Rocket
.524	9.0063	10.00	M	Rocket	Rocket
.568	10.9851	10.00	M	Rocket	Rocket
.800	17.7513	19.50	M	Rocket	Drogue
.834	17.8457	19.50	M	Rocket	Drogue
.879	17.7905	19.50	M	Rocket	Drogue
.900	17.8514	19.50	M	Rocket	Drogue
.999	20.8420	19.50	M	Rocket	Drogue
1.000	20.8890	29.00	F	Drogue	Drogue
1.084	26.0958	29.00	F	Drogue	Drogue
1.085	26.1677	29.00	M	Drogue	Drogue
1.100	27.2576	29.00	M	Drogue	Drogue
1.160	31.7309	29.00	M	Drogue	Drogue

Table 2-16

TF-18A PERFORMANCE STUDY - TEST 1.18 .2 SECOND DELAY

REAR SEAT: 98 Percentile FRONT SEAT: 3 Percentile VELOCITY: 130 Knots

ALTITUDE: 384 Ft. SINK RATE: 0 Ft/Sec PITCH: 0 Degrees ROLL: 180 Degrees

Time	Spatial Sep. (Ft)	Combined Safety Envelope (Ft)	Status	Stage Front Occ.	Stage Rear Occ.
.500	7.9716	10.00	F	Rocket	Rocket
.524	8.9968	10.00	F	Rocket	Rocket
.525	9.0397	10.00	M	Rocket	Rocket
.568	10.9730	10.00	M	Rocket	Rocket
.800	17.7435	19.50	M	Rocket	Drogue
.834	17.8375	19.50	M	Rocket	Drogue
.880	17.7673	19.50	M	Rocket	Drogue
.900	17.8185	19.50	M	Rocket	Drogue
.999	20.6898	19.50	M	Rocket	Drogue
1.000	20.7349	29.00	F	Drogue	Drogue
1.080	25.5585	29.00	F	Drogue	Drogue
1.090	26.2746	29.00	M	Drogue	Drogue
1.160	31.6069	29.00	M	Drogue	Drogue

Table 2-17

TF-18A PERFORMANCE STUDY - TEST 1.19 .2 SECOND DELAY

REAR SEAT: 98 Percentile FRONT SEAT: 3 Percentile VELOCITY: 130 Knots

ALTITUDE: 55 Ft. SINK RATE: 50 Ft/Sec PITCH: -15 Degrees ROLL: 0 Degrees

Time	Spatial Sep. (Ft)	Combined Safety Envelope (Ft)	Status	Stage Front Occ.	Stage Rear Occ.
.500	8.0272	10.00	F	Rocket	Rocket
.522	8.9773	10.00	F	Rocket	Rocket
.523	9.0210	10.00	M	Rocket	Rocket
.566	10.9720	10.00	M	Rocket	Rocket
.800	17.7980	19.50	M	Rocket	Drogue
.830	17.8768	19.50	M	Rocket	Drogue
.881	17.7942	19.50	M	Rocket	Drogue
.900	17.8447	19.50	M	Rocket	Drogue
.999	20.6646	19.50	M	Rocket	Drogue
1.000	20.7094	29.00	F	Drogue	Drogue
1.080	25.5305	29.00	F	Drogue	Drogue
1.090	26.2351	29.00	M	Drogue	Drogue
1.160	31.5488	29.00	M	Drogue	Drogue

Table 2-18

TF-18A PERFORMANCE STUDY - TEST 1.20 .2 SECOND DELAY

REAR SEAT: 98 Percentile FRONT SEAT: 3 Percentile VELOCITY: 130 Knots

ALTITUDE: 20 Ft. SINK RATE: 20 Ft/Sec PITCH: -5 Degrees ROLL: 0 Degrees

Time	Spatial Sep. (Ft)	Combined Safety Envelope (Ft)	Status	Stage Front Occ.	Stage Rear Occ.
.500	8.0501	10.00	F	Rocket	Rocket
.521	8.9620	10.00	F	Rocket	Rocket
.522	9.0060	10.00	M	Rocket	Rocket
.565	10.9707	10.00	M	Rocket	Rocket
.800	17.8581	19.50	M	Rocket	Drogue
.830	17.9331	19.50	M	Rocket	Drogue
.881	17.8419	19.50	M	Rocket	Drogue
.900	17.8914	19.50	M	Rocket	Drogue
.999	20.7008	19.50	M	Rocket	Drogue
1.000	20.7455	29.00	F	Drogue	Drogue
1.080	25.5732	29.00	F	Drogue	Drogue
1.090	26.2794	29.00	M	Drogue	Drogue
1.160	31.6122	29.00	M	Drogue	Drogue

Table 2-19

TF-18A PERFORMANCE STUDY - TEST 2.1b .4 SECOND DELAY

INITIAL VELOCITY: 0 Knots BOTH SEATS DIVERGE LEFT

REAR SEAT: 98 Percentile FRONT SEAT: 3 Percentile

Time	Spatial Sep. (Ft)	Combined Safety Envelope (Ft)	Status	Stage Front Occ.	Stage Rear Occ.
1.260	31.7352	29.00	M	Drogue	Drogue
1.300	30.8540	29.00	M	Drogue	Drogue
1.400	28.6720	29.00	M	Drogue	Drogue
1.500	26.8021	29.00	M	Drogue	Drogue
1.590	26.0540	29.00	F	Drogue	Drogue
1.600	26.0097	29.00	F	Drogue	Drogue
1.700	25.3834	29.00	F	Drogue	Drogue
1.750	25.2633	29.00	F	Drogue	Drogue
1.800	25.7080	37.25	F	Drogue	Recovery
1.900	27.1959	37.25	F	Drogue	Recovery
2.000	28.7803	37.25	F	Drogue	Recovery
2.100	31.3714	37.25	F	Drogue	Recovery
2.165	33.5461	37.25	M	Drogue	Recovery
2.199	34.6917	37.25	M	Drogue	Recovery
2.200	34.7240	45.50	F	Recovery	Recovery
2.300	38.0322	45.50	F	Recovery	Recovery
2.400	40.8876	45.50	F	Recovery	Recovery
2.403	40.9653	45.50	M	Recovery	Recovery
2.500	43.5181	45.50	M	Recovery	Recovery
2.600	46.3944	45.50	M	Recovery	Recovery
2.690	49.7587	45.50	M	Recovery	Recovery

Table 2-20

TF-18A PERFORMANCE STUDY - TEST 2.3b .4 SECOND DELAY

INITIAL VELOCITY: 0 Knots BOTH SEATS DIVERGE LEFT

REAR SEAT: 98 Percentile FRONT SEAT: 98 Percentile

Time	Spatial Sep. (Ft)	Combined Safety Envelope (Ft)	Status	Stage Front Occ.	Stage Rear Occ.
1.800	33.0114	37.25	F	Drogue	Recovery
1.900	31.6953	37.25	F	Drogue	Recovery
2.000	30.3890	37.25	F	Drogue	Recovery
2.100	29.1283	37.25	F	Drogue	Recovery
2.200	27.8490	45.50	F	Recovery	Recovery
2.300	26.6307	45.50	F	Recovery	Recovery
2.400	25.8097	45.50	F	Recovery	Recovery
2.500	25.1203	45.50	F	Recovery	Recovery
2.600	24.6380	45.50	F	Recovery	Recovery
2.700	24.4167	45.50	F	Recovery	Recovery
2.800	23.4897	45.50	F	Recovery	Recovery
2.900	21.5336	45.50	F	Recovery	Recovery
3.000	19.3272	45.50	F	Recovery	Recovery
3.100	17.1574	45.50	F	Recovery	Recovery
3.200	15.1453	45.50	F	Recovery	Recovery
3.300	13.9408	45.50	F	Recovery	Recovery
3.400	13.0346	45.50	F	Recovery	Recovery
3.500	12.2034	45.50	F	Recovery	Recovery
3.600	11.4625	45.50	F	Recovery	Recovery
3.700	10.8287	45.50	F	Recovery	Recovery
3.800	10.3207	45.50	F	Recovery	Recovery
3.900	9.9568	45.50	F	Recovery	Recovery
4.000	9.7517	45.50	F	Recovery	Recovery
4.100	9.7136	45.50	F	Recovery	Recovery
4.180	9.8046	45.50	F	Recovery	Recovery

Table 2-21

TF-18A PERFORMANCE STUDY - TEST 2.4b .4 SECOND DELAY

INITIAL VELOCITY: 0 Knots

BOTH SEATS DIVERGE LEFT

REAR SEAT: 3 Percentile

FRONT SEAT: 3 Percentile

Time	Spatial Sep. (Ft)	Combined Safety Envelope (Ft)	Status	Stage Front Occ.	Stage Rear Occ.
1.800	40.6662	37.25	M	Drogue	Recovery
1.900	39.4378	37.25	M	Drogue	Recovery
2.000	38.1737	37.25	M	Drogue	Recovery
2.100	36.8729	37.25	M	Drogue	Recovery
2.199	35.6291	37.25	M	Drogue	Recovery
2.200	35.6187	45.50	F	Recovery	Recovery
2.300	34.2925	45.50	F	Recovery	Recovery
2.400	33.2325	45.50	F	Recovery	Recovery
2.500	32.4424	45.50	F	Recovery	Recovery
2.600	31.9669	45.50	F	Recovery	Recovery
2.700	31.7284	45.50	F	Recovery	Recovery
2.800	31.5089	45.50	F	Recovery	Recovery
2.900	31.3027	45.50	F	Recovery	Recovery
3.000	30.8549	45.50	F	Recovery	Recovery
3.100	29.1850	45.50	F	Recovery	Recovery
3.200	27.4376	45.50	F	Recovery	Recovery
3.300	25.8733	45.50	F	Recovery	Recovery
3.400	25.2752	45.50	F	Recovery	Recovery
3.500	24.8996	45.50	F	Recovery	Recovery
3.600	24.2190	45.50	F	Recovery	Recovery
3.700	22.9681	45.50	F	Recovery	Recovery
3.800	21.7289	45.50	F	Recovery	Recovery
3.900	20.3327	45.50	F	Recovery	Recovery
3.910	20.1865	45.50	F	Recovery	Recovery

Table 2-22

TF-18A PERFORMANCE STUDY - TEST 2.5b .4 SECOND DELAY

INITIAL VELOCITY: 100 Knots BOTH SEATS DIVERGE LEFT

REAR SEAT: 98 Percentile FRONT SEAT: 3 Percentile

Time	Spatial Sep. (Ft)	Combined Safety Envelope (Ft)	Status	Stage Front Occ.	Stage Rear Occ.
1.243	31.8937	29.00	M	Drogue	Drogue
1.300	30.3800	29.00	M	Drogue	Drogue
1.400	27.6650	29.00	M	Drogue	Drogue
1.457	26.0922	29.00	F	Drogue	Drogue
1.500	25.2229	29.00	F	Drogue	Drogue
1.600	23.4742	29.00	F	Drogue	Drogue
1.700	21.8466	29.00	F	Drogue	Drogue
1.800	21.4150	37.25	F	Drogue	Recovery
1.900	21.6784	37.25	F	Drogue	Recovery
2.000	22.5313	37.25	F	Drogue	Recovery
2.100	23.8347	37.25	F	Drogue	Recovery
2.200	25.6116	45.50	F	Recovery	Recovery
2.300	27.6833	45.50	F	Recovery	Recovery
2.400	28.8147	45.50	F	Recovery	Recovery
2.500	30.1283	45.50	F	Recovery	Recovery
2.600	31.2942	45.50	F	Recovery	Recovery
2.700	33.0725	45.50	F	Recovery	Recovery
2.800	36.2791	45.50	F	Recovery	Recovery
2.900	39.7518	45.50	F	Recovery	Recovery
2.940	41.2526	45.50	M	Recovery	Recovery
3.000	43.6095	45.50	M	Recovery	Recovery
3.100	47.6679	45.50	M	Recovery	Recovery
3.173	50.0393	45.50	M	Recovery	Recovery

Table 2-23

TF-18A PERFORMANCE STUDY - TEST 2.6b .4 SECOND DELAY

INITIAL VELOCITY: 150 Knots BOTH SEATS DIVERGE LEFT

REAR SEAT: 98 Percentile FRONT SEAT: 3 Percentile

Time	Spatial Sep. (Ft)	Combined Safety Envelope (Ft)	Status	Stage Front Occ.	Stage Rear Occ.
1.263	31.8893	29.00	M	Drogue	Drogue
1.300	30.8859	29.00	M	Drogue	Drogue
1.400	28.0593	29.00	M	Drogue	Drogue
1.468	26.0779	29.00	F	Drogue	Drogue
1.470	26.0299	29.00	F	Drogue	Drogue
1.500	25.4282	29.00	F	Drogue	Drogue
1.600	23.1339	29.00	F	Drogue	Drogue
1.700	20.4691	29.00	F	Drogue	Drogue
1.800	18.0257	37.25	F	Drogue	Recovery
1.900	14.8552	37.25	F	Drogue	Recovery
2.000	11.2782	37.25	F	Drogue	Recovery
2.100	8.1744	37.25	F	Drogue	Recovery
2.200	5.4353	45.50	F	Recovery	Recovery
2.300	3.8551	45.50	F	Recovery	Recovery
2.322	3.8216	45.50	F	Recovery	Recovery
2.400	4.2157	45.50	F	Recovery	Recovery
2.500	5.4972	45.50	F	Recovery	Recovery
2.600	9.0702	45.50	F	Recovery	Recovery
2.700	14.2144	45.50	F	Recovery	Recovery
2.800	19.7222	45.50	F	Recovery	Recovery
2.900	26.4810	45.50	F	Recovery	Recovery
3.000	31.7508	45.50	F	Recovery	Recovery
3.095	35.0442	45.50	F	Recovery	Recovery

Table 2-24

TF-18A PERFORMANCE STUDY - TEST 2.7b .4 SECOND DELAY

INITIAL VELOCITY: 200 Knots BOTH SEATS DIVERGE LEFT

REAR SEAT: 98 Percentile FRONT SEAT: 3 Percentile

Time	Spatial Sep. (Ft)	Combined Safety Envelope (Ft)	Status	Stage Front Occ.	Stage Rear Occ.
1.380	31.7667	29.00	M	Drogue	Drogue
1.400	31.3723	29.00	M	Drogue	Drogue
1.500	29.7238	29.00	M	Drogue	Drogue
1.600	28.9720	29.00	M	Drogue	Drogue
1.700	28.2418	29.00	M	Drogue	Drogue
1.800	27.9625	37.25	F	Drogue	Drogue
1.828	27.9439	37.25	F	Drogue	Recovery
1.900	27.9949	37.25	F	Drogue	Recovery
2.000	28.1723	37.25	F	Drogue	Recovery
2.100	28.2766	37.25	F	Drogue	Recovery
2.200	28.2558	45.50	F	Recovery	Recovery
2.300	27.9212	45.50	F	Recovery	Recovery
2.310	27.9084	45.50	F	Recovery	Recovery
2.400	28.4746	45.50	F	Recovery	Recovery
2.500	30.5993	45.50	F	Recovery	Recovery
2.600	33.5366	45.50	F	Recovery	Recovery
2.700	37.4586	45.50	F	Recovery	Recovery
2.764	40.9897	45.50	M	Recovery	Recovery
2.800	43.4467	45.50	M	Recovery	Recovery
2.886	50.0054	45.50	M	Recovery	Recovery

Table 2-25

tests 1.1 through 1.29 and can be found in Appendix D, Figures D-1 through D-58. Plots showing the spatial separation between the rear seat and front seat/occupant/occupant alone system after rear seat/occupant separation and between the front seat and rear occupant after front seat/occupant separation can be found in Appendix D Figures D-59 through D-106. Figures D-107 through D-142 show the spatial separation between the front and rear seat/occupant/occupant alone systems for tests 2.1 through 2.18.

The predicted trajectories and the spatial separation plots for tests 3.1 and 3.2 are shown in Figures D-143 through D-146. The predicted trajectories for tests 4.1 through 4.6 are shown in Figures D-147 through D-152.

3.0 ICARUS PROGRAM MODIFICATIONS

Based on the experiences of CSC task personnel in using the ICARUS Program, it was suggested to LSED personnel that the method of inputting data to the program be modified. These modifications simplify the input data procedure, within the limits of the program, thus making the ICARUS Program easier to use and reducing the possibility of input data errors. The CE agreed to a simplified ICARUS Program input procedure and this was implemented as described in Section 3.1.

While conducting the studies outlined in Section 2, the following problems were discovered in the ICARUS Program:

1. Initialization of conditions at catapult ignition was not always correct.
2. The program could not correctly calculate the time for RISER LINE STRETCH.
3. Euler angles were wrong after ROCKET IGNITION.
4. Acceleration data output in the SUMMARY REPORT was wrong.
5. The program aborted with a Mach Limit error for no apparent reason.
6. The program often terminated because of non-convergence.
7. The program required WORD and DART inputs (Stencel seat variables) in order to run cases which do not need them.
8. The program sometimes aborted with CPU errors.
9. The program could not handle ROCKET BURNOUT and DROGUE EXTRACTION happening simultaneously.

10. The file generated for plotting contained too many points, and the number of points depended upon the integration step sizes used (which can vary from run to run). This was not only costly, but made it difficult to plot the output from 2 runs together.

11. The ISTOP flag, when set, caused the program to run indefinitely. It should cause the program to terminate at occupant alone impact.

12. The data generated after RECOVERY CHUTE FULLY OPENED was erroneous.

13. The program did not always handle seat/occupant/occupant alone impact correctly.

    a. Sometimes it gave a non-convergence message, meaning that it could not find YPOS = 0.

    b. Sometimes it aborted with a CPU error.

    c. In one run, it found RECOVERY CHUTE FULLY OPENED .07 seconds after impact, with YPOS = -.76321 ft.

14. In report 3 (position data), meaningless seat alone data was printed after seat alone impact.

15. The program did not handle the aircraft equations correctly after occupant impact.

The CE requested that problems 1-9 be corrected before further studies would be initiated; problem 10 was to be corrected on a time-permitting basis. Since the program is normally only run to RECOVERY CHUTE FULLY OPENED, and since seat data is not normally tracked, problems 11-15 were

ignored. CSC corrected problems 1-10 as outlined in Section 3.2. In addition, CSC made further modifications both to correct other problems that became apparent while correcting the first set of problems, and to reduce the cost of running ICARUS. These additional modifications are outlined in Section 3.3.

3.1 Simplification of the Input Data Procedure

The ICARUS program input data was originally contained on a default data file, an update data file and a seat/occupant aerodynamic coefficients data file. The default data file consisted of flags and data values only, with no indication, except by sequence, as to which variable the values applied. The update data file consisted of one or more lines, with each line containing a variable name and the associated value. After the ICARUS Program read and stored the data from the default data file, the update data file was read and each specified variable was reassigned the value defined by the update data file. This method of handling the input data involved the use of subroutines ACT, BLKDAT, CONVT, DEFAULT, ENDCASE, INPUT, PTDFLT, TABCONL, TABCRDS, TBLRD, UPDEC, and UPINTG. In addition, the units of the default data file were not consistent.

The concept of a default data file and an update data file was eliminated and replaced with a single input data file. This file retained the same parameter sequence as the default data file but provision was made for including the variable name with each value so that a particular parameter could be readily found and changed.

The input file is divided into 14 logical sections and 15 tables. A header line was added to each section and table, which defines the section number and the number of items in the section, or the table name and the number of points in the table. All input data units were standardized to feet, seconds, pounds, degrees, G's and slugs.

Subroutines DEFAULT, PIDFLT, UPDEC, and UPINTG were eliminated. The functions performed by subroutines BLKDAT, CONVT, INPUT, TABCONL, TABCRDS, and TBLRD were replaced by subroutines BLOCK, CONSTAN, INPUT, TABLE, and TIMEX. Subroutines ACT and ENDCASE were retained with minor modifications.

3.1.1 Description of the Simplified Input Data Subroutines

The input procedure is controlled by the main program ICARUS which calls subroutine EXECUT. Subroutine EXECUT then calls subroutines CONSTAN, INPUT and TIMEX as required. Subroutine INPUT calls subroutine BLOCK, TABLE, ACT, and ENDCASE when needed.

3.1.1.1 Subroutine CONSTAN

This subroutine is called by subroutine EXECUT and sets the constant parameters used by the program.

3.1.1.2 Subroutine INPUT

This subroutine is called by subroutine EXECUT and calls subroutines BLOCK, TABLE, ACT, and ENDCASE as needed. The reading, storage and

printing of the data contained in the input file are controlled by this subroutine. All input data with units of degrees are converted to radians by this subroutine.

3.1.1.2.1 Subroutine BLOCK

This subroutine is called by subroutine INPUT and reads, stores and prints the data contained in the 14 sections of the input file.

3.1.1.2.2 Subroutine TABLE

This subroutine is called by subroutine INPUT and reads, stores and prints the data contained in the 15 tables of the input file.

3.1.1.2.3 Subroutine ACT

This subroutine is called by subroutine INPUT and reads, stores, and optionally prints the data contained in the seat/occupant aerodynamic coefficients file.

3.1.1.2.4 Subroutine ENDCASE

This subroutine is called by subroutine INPUT after the input file has been read and checks for illegal input values.

3.1.1.3 Subroutine TIMEX

This subroutine is called by subroutine EXECUT when the simulation has been completed and it computes and prints the elapsed Central Processor Time.

3.1.2 Description of the Simplified Input Data File

Figure 3-1 illustrates the simplified input data file format. The first line must contain the word START in the first 5 columns and the last line must contain the word STOP in the first 4 columns. If the last line is not the word STOP, the ICARUS program will attempt to read another complete input file. Therefore, any number of runs can be made with a single input data file structured as follows:

```
START
(Data for Run 1)
START
(Data for Run 2)
   .
   .
   .
START
(Data for Run N)
STOP
```

The second and third lines are reserved for a descriptive run title with each line being 80 characters long.

The next 19 lines contain the run option flags. These are entered as 4 parameters per line, except for INT(29), INT(30), and IDFLT, ITABP which are entered as only 2 parameters per line and IRSW(33), IRSW(34), IRSW(35) which are entered as 3 parameters per line as shown by Figure 3-1. The flag names must be 8 characters, including trailing blanks, and are entered in columns 1-8, 21-28, 41-48, and 61-68. The flag values are entered right justified in columns 9-10, 29-30, 49-50, and 69-70.

Following the flags are the 14 data sections. Each section has a header line which defines the section sequence number (1-14 in ascending order) and the number of items in the section. The word SECTION must be in the

```
START
                    ICARUS PROGRAM VALIDATION STUDY
F-18A NWC SNORT SLED TEST 1, 0 KEAS, 98 PERCENTILE DUMMY
ISHA       1           ISTOP      0           ISMS       1           ISEAT      0
INT(5)     1           INT(6)     1           INT(7)     0           INT(8)     0
INT(9)     1           INT(10)    0           INT(11)    0           INT(12)    0
INT(13)    0           INT(14)    0           INT(15)    0           INT(16)    0
INT(17)    0           INT(18)    0           INT(19)    0           INT(20)    0
INT(21)    0           INT(22)    0           INT(23)    0           INT(24)    0
INT(25)    0           INT(26)    0           INT(27)    0           INT(28)    0
INT(29)    0           INT(30)    0
IPROP      1           IPLOT      0           IRECH      0           IAERO      0
IDFLT      1           ITARP      1
IPSW(1)    0           IPSW(2)    1           IPSW(3)    1           IPSW(4)    1
IPSW(5)    1           IPSW(6)    0           IPSW(7)    0           IPSW(8)    0
IPSW(9)    0           IPSW(10)   1           IPSW(11)   0           IPSW(12)   0
IPSW(13)   1           IPSW(14)   1           IPSW(15)   1           IPSW(16)   1
IPSW(17)   1           IPSW(18)   0           IPSW(19)   1           IPSW(20)   0
IPSW(21)   0           IPSW(22)   0           IPSW(23)   0           IPSW(24)   0
IPSW(25)   2           IPSW(26)   0           IPSW(27)   0           IPSW(28)   0
IPSW(29)   0           IPSW(30)   0           IPSW(31)   0           IPSW(32)   0
IPSW(33)   0           IPSW(34)   0           IPSW(35)   0
SECTION  1 CONTAINS  12 ITEMS
PHIC            -90.0          PSIC            -22.0          THETAC             0.0
PHISC            90.0          PSISC             0.0          THETSC             0.0
PSIV             0.00          VROC             0.00          AAT                0.0
YAW              0.00          PITCH             0.0          ROLL              90.0
SECTION  2 CONTAINS  76 ITEMS
XAC               0.0          YAC               0.0          ZAC                0.0
XCS               1.0          YCS            1.0633          ZCS                0.0
XCDC              0.0          YCDC       3.96166667          ZCDC               0.0
XCPC              0.0          YCPC       3.96166667          ZCPC               0.0
XCM             1.202          YCM             .9808          ZCM                0.0
XCRDL            -0.0          YCRDL            -0.0          ZCRDL             -0.0
XCLDL            -0.0          YCLDL            -0.0          ZCLDL             -0.0
XCRREO     -0.0833333          YCRREO            0.0          ZCRREO      0.41666667
XCLREO     -0.0833333          YCLREO            0.0          ZCLREO      -0.4166667
XCRCHA            0.0          YCRCHA           3.75          ZCRCHA       0.4166667
XCLCHA            0.0          YCLCHA           3.75          ZCLCHA      -0.4166667
XCRCC            -0.0          YCRCC            -0.0          ZCRCC             -0.0
XCRR              0.0          YCRR       3.96166667          ZCRR               0.0
XCLR              0.0          YCLR       3.96166667          ZCLR               0.0
XCSA            .5733          YCSA           1.2375          ZCSA               0.0
XCSCG           .3675          YCSCG            .495          ZCSCG              0.0
XCMCG           1.202          YCMCG           .9808          ZCMCG              0.0
XCSACG          .3675          YCSACG           .495          ZCSACG             0.0
XCWRDA           -0.0          YCWRDA           -0.0          ZCWRDA            -0.0
XCWRDR           -0.0          YCWRDR           -0.0          ZCWRDR            -0.0
XCRSBR        1.03125          YCRSBR      -.5308333          ZCRSBR       .66416667
XCLSBR        1.03125          YCLSBR      -.5308333          ZCLSBR      -.66416667
XCRCP            -0.0          YCRCP            -0.0          ZCRCP             -0.0
XCLCP            -0.0          YCLCP            -0.0          ZCLCP             -0.0
YSEAT             0.0          XCP            0.9980          YCP              4.446
ZCP               0.0
SECTION  3 CONTAINS  14 ITEMS
XA            -.68592          YA               00.0          ZA                 0.0
FDW               0.0          FLW               1.0          FTW                0.0
FCW               0.0          VAO               0.0          MUDOT              0.0
PDA               0.0          QDA               0.0          RDA                0.0
TEAR            82.00          PMAS           931.20
SECTION  4 CONTAINS   6 ITEMS
ARSBR         89.0000          PRSBR            15.0          GPSBR         105.0000
```

FIGURE 3-1

```
ALSBR          89.0000          BLSBR          15.0          GLSBR          75.0000
SECTION  5 CONTAINS    5 ITEMS
KX             -0.0             KY             -0.0          KZ             -0.0
MUF            -0.0             XSBTOL         -0.0
SECTION  6 CONTAINS    3 ITEMS
LDL0           -0.0             LDL1           -0.0          FADART         -0.0
SECTION  7 CONTAINS   40 ITEMS
IXXS           25.5             IXYS            0.0          IXZS            0.0
IYYS           28.5             IYZS            0.0          IZZS            8.2
IXXM           11.92            IXYM            0.0          IXZM            0.0
IYYM           15.04            IYZM            0.0          IZZM            5.69
IXXSA           4.0             IXYSA           0.0          IXZSA           0.0
IYYSA           5.0             IYZSA           0.0          IZZSA           1.0
GWS           445.0             GWM           302.0          GWSA          143.00
GWBRD          -0.0             GWC             1.00         GWDC            6.0
GWPC           16.50            SS              7.5          SH              9.6
SSA             6.0             WX              0.0          WY              0.0
WZ              0.0             BBARS           1.545        BBARM           1.748
BBARSA          1.38            CREW            0.0          TRAVEL          4.7
SCREN0          1.0             SCREN1          0.0          SUN             0.0
CPCG            0.85
SECTION  8 CONTAINS   16 ITEMS
KSDC         2000.0             KSWRD          -0.0          KSPC         2000.0
ALTRO        6000.0             SSDC           78.54         DODC            7.9531
DORC           27.4829          SC              0.5          SVRD           -0.0
UDP             0.0             VDP             0.0          WDP           -55.0
FOSO            0.0             KSODC          20.0          KSORC          16.0
TAUEXP          3.0
SECTION  9 CONTAINS   10 ITEMS
LWRDL          -0.0             LDCL            3.0          LSLDC          12.0
LFL            -0.0             LRISER          2.50         LSLRC          20.0
LSG            -0.0             CATSTK          6.06         DWPDCG         -0.0
LRECOV         14.0
SECTION 10 CONTAINS    9 ITEMS
TCI              .313           TCH              .313        TPI            -0.0
TRRO           -0.0             TDP            -0.0          TWRDI          -0.0
TWRDRO         -0.0             TSTOP           6.0          PREDO          10.0
SECTION 11 CONTAINS   24 ITEMS
STO             0.0             DTAIR           0.005        DTCI            0.001
DTSBR           0.001           DTDP             .001        DTDE             .001
DTWI           -0.0             DTRCO           0.001        DTRCF            .01
DTSMS            .01            STAR           -0.0          ALPHAT         -0.0
CNT            -0.0             XTAR           -0.0          ZTAR           -0.0
CMQ            -0.0             PCP            -0.0          P0              0.0
Q0              0.0             R0              0.0          CLPMA          -0.0
CMQMA          -0.0             CNRMA          -0.0          RRC            -0.0
SECTION 12 CONTAINS   12 ITEMS
CX            404.22            XSLACK          0.083        SXP         33286.19
SXN         33286.19            CY            404.22         SY          33286.19
CZ            166.43            ZSLACK          0.166        SZP         33286.19
ZROT           -0.074           SZN1        17131.29         SZN2        42484.3
SECTION 13 CONTAINS   20 ITEMS
XKSLIP      35000.0             ZKSLIP      20000.0          XCSLIP        200.0
ZCSLIP        200.0             UNSLIP          0.025        XYKTOR        261.780105
XYCTOR          1.74520070      UMTUBE          0.025        FKTUBE      20000.0
FCTUBE        100.0             POWER           0.25         SBCOEF      75000.0
TUBLTH1         2.78            TUBLTH2         3.28         TUBLTH3         3.66
XCTCP           0.0             YCTCP           3.75         ZCTCP           0.0
STNCEL          1.0             RAILNT          3.66
SECTION 14 CONTAINS    7 ITEMS
TMLAP1          0.589           TMLAP2          1.558        ALT2        13000.0
ALT1         6000.0             TIM2GZ          3.0          SMSEPF         80.0
SBRON           6.0
TABLE TCL       CONTAINS   25 POINTS
     0.0     .010     .020     .030     .040     .050     .060     .070
   0.080     .090     .100     .110     .120     .130     .140     .150
```

FIGURE 3-1 (CONTINUED)

```
     .160       .170       .180       .190       .200       .210       .220       .230
     .250
      0.0      777.0     1074.5     1441.0     1911.0     2344.9     2765.0     2934.0
   2826.0     2543.5     2246.5     2054.5     1659.5     1719.5     1804.5     1992.5
   2206.0     2386.0     2567.0     2557.0     2437.5     2193.0      959.0      624.5
      0.0
TABLE TCR      CONTAINS  25 POINTS
      0.0       .010       .020       .030       .040       .050       .060      0.070
     .080       .090       .100       .110       .120       .130       .140       .150
     .160       .170       .180       .190       .200       .210       .220       .230
     .250
      0.0      777.0     1074.5     1441.0     1911.0     2344.9     2765.0     2934.0
   2826.0     2543.5     2246.5     2054.5     1659.5     1719.5     1804.5     1992.5
   2206.0     2386.0     2567.0     2557.0     2437.5     2193.0      959.0      624.5
      0.0
TABLE TLR      CONTAINS  10 POINTS
.000       .010       .020       .060       .130       .180       .196       .215
.250       .260
0.0        1585.32    1501.80    1540.32    1534.74    1512.63    1454.75    1361.80
  22.60      0.00
TABLE TRR      CONTAINS  10 POINTS
.000       .010       .020       .060       .130       .180       .196       .215
.250       .260
0.0        3176.63    3003.60    3080.63    3069.47    3025.54    2909.48    2722.79
  45.19      0.00
TABLE CDC      CONTAINS   2 POINTS
      0.0     1000.0
      1.0        1.0
TABLE CNDC     CONTAINS   2 POINTS
      0.0      180.0
      0.0        0.0
TABLE CTDC     CONTAINS   2 POINTS
      0.0      180.0
     .755       .755
TABLE CNRC     CONTAINS  11 POINTS
      0.0        5.0       10.0       15.0       20.0       25.0       30.0       35.0
     37.0       75.0      180.0
      0.0       -.02       -.03       -.01        0.0        .03        .07        .13
      .18        1.5        1.5
TABLE CTRC     CONTAINS  11 POINTS
      0.0        5.0       10.0       15.0       20.0       25.0       30.0       35.0
     37.0       75.0      180.0
      1.5       1.52       1.54       1.54       1.52       1.50       1.46      1.375
    1.325        0.0        0.0
TABLE TDGFFI   CONTAINS   2 POINTS
    0.000     1000.0
    0.709      0.709
TABLE TRSRLS   CONTAINS   2 POINTS
    0.000      500.0
    1.093      1.093
TABLE TRLSFI   CONTAINS   2 POINTS
    0.000      500.0
    2.736      2.736
TABLE CDWRD    CONTAINS   2 POINTS
     -0.0       -0.0
     -1.0       -0.0
TABLE TWRD     CONTAINS   2 POINTS
     -0.0       -.24
     -0.0       -0.0
TABLE VCSB     CONTAINS   6 POINTS
      0.0        0.0        0.0        0.0        0.0        0.0
      0.0 1.9266667 3.5266667        0.0 1.9266667 3.5266667
 0.1458333 0.1458333 0.1458333 -0.145833 -0.145833 -0.145833
AERODYNAMIC COEFFICIENTS FILE CONTAINS 12 TABLES
CXS      1
CYS      2
```

FIGURE 3-1 (CONTINUED)

```
CZS       3
CLS       4
CMS       5
CNS       6
CXM      21
CYM      22
CZM      23
CLM      24
CMM      25
CNM      26
STOP
```

FIGURE 3-1 (CONTINUED)

first 7 columns and the section sequence number is entered (integer, right justified) in columns 9-10. The number of items is entered (integer, right justified) in columns 21-23. The section data is entered as 3 items per line until the number of items specified has been entered. The parameter names must be 7 characters, including trailing blanks, and are entered in columns 1-7, 31-37, and 61-67. The parameter values are entered as real numbers in columns 8-20, 38-50, and 68-80.

After the 14 sections, there are 15 tables. These tables must be entered in the following sequence: TCL, TCR, TLR, TRR, CDC, CNDC, CTDC, CNRC, CTRC, TDGFFI, TRSRLS, TRLSFI, CDWRD, TWRD, and VCSB. Each table contains a header line which defines the table name and the number of points in the table. A point consists of an independent and a dependent variable, except for the VCSB table where a point consists of 3 coordinates. The word TABLE must be in the first 5 columns; the table name is 7 characters including trailing blanks in columns 7-13. The number of points is entered (integer, right justified) in columns 24-26. The table independent variable values are then entered, as real numbers, 8 values per line, in columns 1-10, 11-20, 21-30, 31-40, 41-50, 51-60, 61-70, and 71-80, until the specified number of points has been entered. The dependent variables are then entered in the same format on the following lines.

Finally, following the last table, the seat/occupant aerodynamic coefficient file size is defined by a header card specifying the number of aerodynamic coefficient tables (columns 40-41, integer, right justified) that are contained in the file. The subsequent lines contain the aerodynamic

coefficient table names (7 characters including trailing blanks in columns 1-7), and the table sequence number (integer, right justified) in columns 8-10. These lines are repeated until the specified number of aerodynamic coefficient tables has been entered.

The very last line in the input file must contain the word STOP in the first 4 columns.

3.2 Modifications Made to Correct Problems

Each of the 10 problems that were corrected as requested by the CE is listed below with an explanation of the cause or causes and the modifications made to correct the problem.

3.2.1 Correct the Initialization of Conditions at Catapult Ignition

This problem was twofold. First, the initial seat/occupant acceleration components were calculated incorrectly. Secondly, the call to subroutine PROUT, which prints the output reports, was made before the initial values (that is, the data at catapult ignition) was calculated. Subroutine INIT was modified to calculate the initial acceleration components using the EFCS to SMCS direction cosine transformation matrix ASE; subroutine EXECUT was modified to call PROUT at the proper time (after the call to INIT).

3.2.2 Modify the Program to Determine the Time for RISER LINE STRETCH by Interpolating from a Table of Input Variables

The table shown in Table 3-1 was implemented in ICARUS to determine the time of RISER LINE STRETCH based on the seat/occupant velocity at

VELOCITY AT SHACKLE RELEASE (FT/SEC)	TIME FROM SHACKLE RELEASE TO RISER LINE STRETCH
0	2.409
50	1.658
100	1.111
150	.734
200	.497
250	.367
300	.313
350	.305
400	.303
450	.288
500	.220

TABLE 3-1

shackle release. The values in this table were obtained from test data gathered at the Naval Weapons Center (NWC) and the Naval Parachute Testing Range (NPTR) for the F-18A Aeroconical Parachute. This table can be easily modified if additional data is received or if a different parachute is to be modeled. RISER LINE STRETCH can be forced to occur at a specific time by setting all of the times in the table to the desired value. Subroutine STATUS was modified to implement this table.

3.2.3 Correct the Program's Calculations of Euler Angles During Catapult and Rocket Stages

Several modifications were made to the program to correct this problem.

3.2.3.1 Dynamic C.G. Equations

The equations to simulate the dynamic C.G. movement of the seat/occupant system during the early stages of the ejection were implemented incorrectly, mixing forces and accelerations, as follows:

$$Ax(t) = \ddot{x} + (Cx)\,\dot{x} + F(x)$$

$$Ay(t) = \ddot{y} + (Cy)\,\dot{y} + (Sy)\,y$$

$$Az(t) = \ddot{z} + (Cz)\,\dot{z} + F(z)$$

The motion of the C.G. as calculated by these equations affected the rotation of the seat/occupant system. These equations were reformulated and implemented in subroutine CENGRV. The correct equations are:

$$Ax(t) = -\ddot{x} - cx\,(\dot{x}/m) - F(x)/m$$

$$Ay(t) = \ddot{y} - cy\,(\dot{y}/m) - (Sy)y/m$$

$$Az(t) = \ddot{z} - cz\,(\dot{z}/m) - F(z)/m$$

3.2.3.2 Drogue Chute Attachment Point

The WORD attachment point defined for the Stencel seat was being used as the Drogue Chute attachment point to calculate the vector from the seat/occupant to the drogue chute. This caused the seat/occupant to tumble during the drogue stage. Subroutine CHUTFM was modified to use the drogue attachment point.

3.2.4 Correct the Acceleration Data Output in the Summary Report

The method used by ICARUS to calculate the seat/occupant acceleration was not incorrect. The data output in the Summary Report was incorrect because of some of the other problems.

3.2.5 Determine Why the Program Aborts With a Mach Limit Error

In order to use the aerodynamic coefficients measured in the wind tunnel tests and implemented in ICARUS, only the linear velocities of the seat/occupant should be considered in calculating the Mach number. However, the approach taken in the program also considers the angular velocities of the seat/occupant. These can, at times, be momentarily very large (for example, at parachute opening). The maximum Mach number allowed in determining the aerodynamic coefficients is 1.2, which should never be exceeded when using only the linear velocities. However, since the program can calculate very large angular velocities, this number could be exceeded, thus causing the program to abort with a Mach Limit error.

To correct the program to just consider linear velocities is a major effort, so the following patch was implemented: immediately after being calculated and before being used, the Mach number is tested. If it is

greater than 1.2, it is set equal to 0.4 (a Median Mach number). The program, therefore, will not abort, and in the one test in which this problem occurred, it stabilized past the time of the problem. However, there is no guarantee that the program will always stabilize after the Mach Limit error. The error message is still printed for informational purposes.

3.2.6 Determine the Reason for the Non-Convergence Errors and Correct the Problem

The non-convergence error occurred under two circumstances: when the program was trying to find an altitude of 0' $\pm$ .1' (for impact) and when the program was trying to find a recovery chute force of SMSEPF $\pm$ 1 lb. (for seat/occupant separation). The non-convergence error message printed does not reflect a problem in the program, but merely informs the user that after 15 iterations, the program failed to find the desired values. The program continues, using the last value calculated. Because there is no error in the program, no change could be made to correct the problem. Originally, the following changes were made to subroutine CKVARB to alleviate the problem:

1. The epsilon values were increased. The program will now try to find an altitude of 0' $\pm$ .2' for impact and a recovery chute force of SMSEPF $\pm$ 5 lbs. for seat/occupant separation. This decreases the frequency of non-convergence errors.

2. The error message is printed as a separate report after all desired reports are printed. This will allow the user to know that non-convergence occurred and what value was used by the program. If that value is not acceptable, the run can be remade, lowering the appropriate integration step size. If the value is acceptable, the non-convergence report can be thrown away and the rest of the output used as is.

ICARUS was further modified to define seat/occupant separation when RCFORC $\geq$ SMSEPF. The implication of this change is that the program no longer tries to find the exact time the recovery chute force is SMSEPF $\pm$ 5 lbs. Thus, non-convergence can no longer occur at seat/occupant separation.

3.2.7 Eliminate the Necessity of Inputting STENCEL Seat Variables for Martin-Baker Seat Simulations

Subroutine ENDCASE was modified to allow all inputs not applicable to the Martin-Baker seat to be set to zero when running a Martin-Baker simulation.

3.2.8 Determine Why the Program Aborts With CPU Errors and Correct the Problem

The CPU errors encountered in the program seemed to have been a result of the other problems.

3.2.9 Make the Necessary Modifications to Allow ROCKET BURNOUT and DROGUE EXTRACTION to Occur Simultaneously

To correct this problem a major rewrite of the subroutine STATUS would be required. However, using values of .001 for the input integration step sizes DTCI, DTDP, DTSBR and DTDE alleviates the problem.

3.2.10 Simplify the Plotting File Created by ICARUS

When the code to output a file of data for plotting was implemented in ICARUS, data was written at every integration time step. Modifications were made to the subroutine CUTTAPE to write data every .1 seconds and at every event. In addition to reducing the size of the plotting files, the modification reduced the cost of making ICARUS runs by approximately 20% and of making ICARUS plots by about 500%.

3.3 Additional Modifications Made

The following describes additional modifications made to ICARUS by CSC, either to correct additional problems encountered or to decrease the cost of running ICARUS.

3.3.1 Input Variables Corrected

While debugging the ICARUS program, CSC discovered that erroneous values were being used for several input variables. Table 3-2 lists these variables, a description of each variable, the erroneous value and the correct value.

VARIABLE	DESCRIPTION	PREVIOUS VALUE USED	CORRECT VALUE
XCRSBR	X-Coord. of right rocket position	1.	1.03125
XCLSBR	X-Coord. of left rocket position	1.	1.03125
ARSBR BRSBR GRSBR	Right rocket thrust Line angles (α, β, γ)	89.0341 1.0 90.2588	89 15 105
ALSBR BRSBR GRSBR	Left rocket thrust Line angles (α, β, γ)	89.0341 1.0 89.7412	89 15 75
IXYSA	Seat alone moment of inertia	1	.0
DODC	½ circumference of inflated drogue chute	5.	7.8531
DORC	½ circumference of inflated recovery chute	17.5	27.4889
WDP	Projection velocity of drogue chute	-385.	-55.
KSRC	Recovery Chute Spring Constant	250	2500
CX	Damping constant	50	404.22
SXP	Slope Positive (Forward)	6000	33286.19
SXN	Slope Negative (Backward)	6000	33286.19
CY	Damping Constant	50	404.22
SY	Slope	6000	33286.19
CZ	Damping	30.	166.43
ZSLACK	Upward Slack	.083	.166
SZP	Slope Positive (Upward)	6000	33286.19
ZBOT	Bottoming Distance	-.083	-.074
SZN1	Slope Negative (Down) 1 (Flesh and Cushion)	3088	17131.29
SZN2	Slope Negative (Down) 2 (Seat Kit)	7658	42484.28

TABLE 3-2

3.3.2 Parachute Simulation

Several changes were made to the parachute simulation portions of the program. To effect these changes, subroutines CHUTFM, RECOV, and DROCHU were modified.

1. During the recovery chute stage, the distance from the chute to the seat/occupant is now kept within the maximum allowed value defined by the length of the recovery chute lines. In the original program, there was no limit to how far away from the seat/occupant the chute could move. This change also applies to the drogue chute.

2. At RISER LINE STRETCH, the velocity of the chute is now calculated based on the velocity of the seat/occupant (or occupant alone, after separation). The force of the recovery chute on the seat/occupant/occupant alone is calculated based on this velocity and is used in the seat/occupant/occupant alone equations of motion. In turn, the force of the seat/occupant/occupant alone on the recovery chute is treated as an external force on the recovery chute and is used in the recovery chute equations of motion. This change also applies to the drogue chute simulation after the drogue lines have stretched.

3. In the original program, the WORD force calculated was used in the recovery chute equations to pull out the recovery chute. Subroutine CHUTFM was modified so that the drogue chute force is used instead.

4. There are 5 phases defined for the recovery chute simulation portion of the program. However, the phases defined for the recovery chute modelled by the original program do not correctly model the recovery chute currently being used. These 5 phases were redefined as follows:

	OLD	NEW
Phase 1	Canopy Extraction	Canopy Extraction
Phase 2	Firing Lanyard Extension	Recovery Chute Line Extension
Phase 3	Recovery Chute Line Stretch/Opening	Seat/Occupant/Recovery Chute During Opening
Phase 4	Occupant Alone/Recovery Chute During Opening	Occupant Alone/Recovery Chute During Opening
Phase 5	Occupant Alone/Recovery Chute After Full Inflation	Occupant Alone/Recovery Chute After Full Inflation

5. The message RISER LINE STRETCH was printed by the original program to indicate the beginning of recovery chute suspension lines/riser lines extension. The message now reflects the fact that the recovery chute riser lines have stretched.

6. The call to INITDR (the subroutine which initializes the drogue chute and recovery chute positions and velocities) was incorrect for the initialization of the recovery chute conditions. The call has been changed from

   CALL INITDR (WORK(IRE + 4), XSRC, YSRC, X) to

   CALL INITDR (WORK(IRE + 4), XSRC, XSRC, X)

3.3.3 Drogue Chute Full Inflation Time Calculation

Two modifications were made to the calculation of the time for DROGUE CHUTE FULL INFLATION.

1. The table inputs give the delta time between DROGUE GUN FIRING and DROGUE CHUTE FULL INFLATION based on the velocity of the seat/occupant at DROGUE GUN FIRING. However, ICARUS was calculating the delta time from DROGUE EXTRACTION to DROGUE CHUTE FULL INFLATION, based on the velocity of the seat/occupant system at DROGUE EXTRACTION. Subroutine STATUS has been modified to calculate this delta time at DROGUE GUN FIRING (DROGUE PROJECTION) rather than at DROGUE EXTRACTION.

2. Each time through the subroutine DROCHU, the program recalculated the time for DROGUE CHUTE FULL INFLATION from the input tables, causing DROGUE CHUTE FULL INFLATION to happen at the wrong time. This code was removed.

3.3.4 Bypass Integration of WORD Equations

To decrease the cost of running ICARUS, subroutines STATUS and FETCH were modified to eliminate the integration of the WORD equations when running a Martin-Baker seat simulation. Also, subroutine STATUS was modified so that it no longer checks for WORD IGNITION, when running a Martin-Baker seat simulation.

3.3.5 Removal of Calls to IDEBUG

Each time through subroutine REP1, subroutine IDEBUG was called three times. IDEBUG merely checked an input flag (which is always zero) and returned if zero. These calls have been removed.

3.3.6 Removal of Call to DARTFM

Each time through subroutine SEATMAN, until SEAT/OCCUPANT SEPARATION, the subroutine DARTFM was called. DARTFM calculated the DART forces and moments, which are not applicable to the Martin-Baker seat. Upon return, SEATMAN set the DART forces and moments to zero. This call was removed.

3.3.7 Calculation of Drogue Chute and Recovery Chute Angle of Attack

The following equations appear in the subroutines DROCHU and RECOV respectively:

ALPHDC = ACOS [-(XWRDDC * XDADC - YWRDDC * QY (2) - ZWRDDC * ZDADC)/ (DWRDDC + VDC)]

ALPHRC = ACOS [-(XRRC * XDARC - YRRC * QY (2) - ZRRC * ZDARC)/ (DRRC * VRC)]

Due to the way the program calculates XRRC, YRRC, ZRRC, DRRC and XWRDDC, YWRDDC, ZWRDDC, DWRDDC, the absolute value of the expression inside the brackets can exceed 1. This results in a CPU error, since the ACOS function is not defined for these values. Code has been inserted to test the values of the expression inside the brackets. If it is greater than 1, it is set to 1; if it is less than -1, it is set to -1.

3.3.8 Printout of Event Messages

Subroutine STATUS has been modified to print the event messages DROGUE CHUTE FILLED, RISER LINE STRETCH, SEAT/OCC SEPARATION, and SEAT ALONE IMPACT once instead of twice. Also the following event messages have been modified as follows:

SEAT BACK ROCKET IGNITION has been changed to ROCKET IGNITION

SEAT BACK ROCKET BURNOUT has been changed to ROCKET BURNOUT

SEAT/MAN SEPARATION has been changed to SEAT/OCC SEPARATION

MAN ALONE IMPACT has been changed to OCC ALONE IMPACT

3.3.9 Stop at Recovery Chute Full Inflation

Subroutine EXECUT was modified to stop at RECOVERY CHUTE FULL INFLATION or when time = TSTOP, whichever comes first, if the input variable INT(6) is set to 1.

3.3.10 Removal of IRECH Flag Check

The input flag IRECH was tested twice, each time through the subroutine RECOV (the flag was apparently used for debugging purposes). If IRECH is 1, recovery chute data is printed. Since IRECH is always Ø, this code is never used and has therefore been removed.

3.3.11 Modify Title Output for Report 18 (Dynamic Response Index)

When report 18 (the Dynamic Response Index) was implemented, the title printed on the report was DYNAMIC REFLEX INDEX. This has been changed to DYNAMIC RESPONSE INDEX.

4.0 ICARUS PROGRAM VALIDATION STUDY

A preliminary study to validate the ICARUS Aircrew Automated Escape System Simulation Model was performed in June 1979. Because of changes and corrections that were made to ICARUS, it became necessary to perform this study in order to validate the performance of the modified program. The results of this preliminary study were furnished to NADC's Life Support Engineering Division as part of Task Order No. 23's June 1979 Technical Status Report. Subsequently, the Task Order Cognizant Engineer requested that a more complete ICARUS validation study be performed and included in the Task Order No. 23 Final Report. The results of that study are contained in this section.

The preliminary study consisted of comparisons between ICARUS simulations and test data from the F-18A sled tests conducted at the SNORT facility of NWC. These simulations were based on a typical rocket thrust versus time curve with the rocket burn time adjusted to agree with the actual test rocket burn time. These thrust vs. time curves were subsequently modified by LSED personnel to insure that the rocket's total impulse would remain the same as the typical rocket for all of the F-18A test simulations. The simulation results obtained with these revised thrust curves appear in this report.

4.1 Purpose

A validation study using F-18A Sled Test Data was performed to demonstrate and validate the capability of the ICARUS Program to accurately predict the motion of an ejection seat. This study shows that the ICARUS Program,

with proper modifications, can be used with confidence to predict and verify the performance of any ejection seat under varying conditions and specifications.

4.2 Method

The validation effort was conducted by comparing actual NWC SNORT F-18A sled test data to simulation results for the same conditions and specifications. Due to variations, inaccuracies and uncertainties in the test parameters, it is not possible to exactly duplicate actual test performance. Therefore, a predicted value within ± 10% of the actual test data is considered to be good agreement.

The CE requested that this study limit itself to the NWC SNORT F-18A sled tests. These 8 tests are defined in Table 4-1.

Test 4 was an intentional ejection through the closed canopy, but no attempt was made to modify the input data to the ICARUS program to account for this situation, since it was assumed that the force necessary to break the canopy would have no appreciable effect on the final trajectory. Also, this test has a gap in the recorded test data from a time of 2.106 seconds after ejection to 5.515 seconds after ejection. Test 5 exhibits an inordinately long time for the main parachute pack opening to occur after the drogue parachute is fully inflated. This test also has no recorded data beyond 2.955 seconds after ejection. Tests 6 and 8 are the high speed tests for the 98 percentile dummy. Both of these tests are considered as suspect,

NWC SNORT F-18A ESCAPE SYSTEM SLED TESTS

TEST NUMBER	TARGET EJECTION VELOCITY (KEAS)	PILOT DUMMY PERCENTILE
1	0	98
2	225	98
3	0	3
4	225	3
5	435	3
6	435	98
7	600	3
8	600	98

Table 4-1

since their trajectory performance is considerably less than the 3 percentile dummy high speed tests 5 and 7. These suspect tests are included in this study to illustrate their deviation from the ICARUS Program predictions and the 3 percentile dummy tests. The ICARUS Program simulation results were obtained from computer runs for the 8 NWC SNORT F-18A sled tests. A listing of the ICARUS program input parameters used for these runs is provided in Appendix J. The velocities that are calculated and output by the ICARUS Program are ground speeds and as such include the components of the reported wind velocities. Since the reported wind data furnished for some of the tests is contradictory in terms of the wind velocity and direction, it was decided to execute the ICARUS computer runs with zero wind conditions. Most of the reported wind velocities were small (5 knots or less) except for tests 3 and 5 which had reported wind velocities of 6 and 7 knots respectively. Winds of this magnitude and reported direction of 210° would have down-range and off-range components of approximately 10 and 12 ft/sec respectively and would have made an incremental change in down-range and off-range ICARUS Program predicted trajectories.

The actual test data for the NWC SNORT F-18A tests were obtained from reports prepared by NWC. The reports for tests 2 through 8 contain the notation that "all velocities have been corrected to sea level dynamic pressure and still air". It is assumed that this statement means that the velocities were corrected to sea level, standard day atmospheric conditions with no winds. Although this note is not provided in the reports for tests 1 and 2, an examination of the data indicates

that the same procedure was also used in these tests. The atmospheric density (slugs/ft^3) for the ambient conditions of these 8 tests ranged from 0.00211 to 0.00199 resulting in an average of 0.00206. Based on the sea level, standard day density of 0.0023769 and the fact that the velocity correction is a function of the square root of the density ratio, the velocities listed in the NWC test reports are approximately 7.4% less than the velocities that would be calculated from the test time and distance (corrected to zero wind conditions) relationships. Since the distance data of the NWC reports are tabulated with only one decimal place as compared to three decimal places for the time data it was not possible to accurately calculate the test ground speeds from these times and distances.

The above restrictions cause a comparison of the simulation and test data to differ by the effect of the reported wind components on the down-range and off-range distances and the effect of the test velocity correction to "sea level dynamic pressure and still air" conditions. Therefore, any velocity comparisons in this study are intended to illustrate trends, but only approximate magnitudes. The effect of the reported wind components on the down-range and off-range distances should not be large and the down-range comparisons should be valid for both trends and magnitudes.

The simulation data is compared to the actual test results by plotting specific comparison parameters against the horizontal velocity at the time of ejection. The selected comparison parameters are defined in Table 4-2.

COMPARISON PARAMETERS

SYMBOL	DEFINITION	POSITIVE SIGN
X	Horizontal Distance	Down-Range from point of ejection
Y	Vertical Distance	Upward
Z	Lateral Distance	Off-range to the right, facing forward
Vx	Horizontal Velocity	Down-range from point of ejection
Vy	Vertical Velocity	Upward
Vz	Lateral Velocity	Off-range to the right, facing forward

TABLE 4-2

Since the horizontal velocity at the time of ejection is the test variable that has the most effect on the trajectory performance, the comparison will be based on a graph of each of the comparison parameters relative to the horizontal velocity at the time of ejection. A graph will be presented for each combination of comparison parameter, dummy percentile and trajectory event. The events that define the ejection trajectory are listed in Table 4-3.

The graphs for these events illustrate any disagreement between the predicted and actual test data, and they isolate the ejection trajectory event at which any deviation occurs. Agreement can be shown in terms of magnitude and also in terms of trends, as a function of the horizontal velocity at the time of ejection, for a particular percentile dummy.

4.3. Analysis

The ICARUS simulation data was obtained from listings of the computer runs made for the LSED, and this data is tabulated in Tables E-1 through E-8 in Appendix E. Data for the actual NWC SNORT F-18A sled tests was derived form NWC Test Reports, and this data is tabulated in Tables E-9 through E-16. Tables E-8 and E-16 contain data for the peak trajectory height, where the peak trajectory is defined as occurring at the time that the vertical velocity is closest to zero.

Since the NWC Test Reports do not provide any angular orienation data, there was no attempt made to graphically compare ICARUS simulation angular data to test data. However, since the angular positions of the seat/occupant at rocket ignition and during the rocket burn phase have

EJECTION TRAJECTORY EVENTS

1. Rocket ignition
2. Rocket burnout
3. Drogue gun fire
4. Drogue parachute full inflation
5. Main parachute pack opening
6. Main parachute riser line stretch
7. Main parachute full inflation

TABLE 4-3

a dominant effect on the ejection trajectory, films of the eight NWC SNORT F-18A sled tests were studied to estimate the approximate angular positions during the early stages of the ejections. The results of this film study are tabulated in Table 4-4. The cockpit guide rails are pitched back 22° from the vertical, and for all the tests there was no appreciable sideslip or roll to be seen at the time of rocket ignition. The tabulated angles are gross approximations made from viewing the films, and are intended to describe the approximate orientation of the seat/occupant at rocket ignition and burnout. All angles are measured while facing forward with pitch, roll, and sideslip being positive back from the vertical, positive to the right and positive to the left respectively.

The test films illustrate the progressively larger catapult tube bending due to the increased dynamic pressures as the test velocities at ejection are increased. Tests for both the 3 and 98 percentile dummies exhibit similar catapult tube bending trends as a function of test velocity.

The poor pitch and roll orientation at rocket ignition and during the rocket burn should account for the low trajectory performance of test 8. It must be noted that the tube bending equations of the ICARUS program were empirically derived and the associated input parameters must be estimated by trying to match given test data. This is also the case for the cockpit partial exposure parameters. In the absence of reliable test data, a best estimate of these parameters must be made, and the ICARUS program runs were conducted using best estimates based on past

tests. These assumptions appear to be adequate since the angular orientations at rocket ignition from the ICARUS simulations are close to the estimated values derived from the test films. However, these assumptions are not valid for tests 7 and 8. This is due to the fact that the ICARUS program tube bending equations assume that no plastic deformation of the tube will occur and tests 7 and 8 exhibited on obviously deformed catapult tube.

All of the test films (including the Ø KEAS tests) showed a sideslip of rotation of the seat after rocket ignition. The magnitude of this rotation increases as a function of test velocity. In seven of the eight tests, the seat/occupant turned to the left, while in test number 5 the rotation was to the right. With the given input test parameters, the ICARUS program does not predict sideslip rotations of these magnitudes and they cannot be explained or justified for an assumed symmetrical seat/occupant. The net effect of these sideslip rotations is to alter the divergence performance of the ejection seat as compared to the ICARUS program predicted values. The down-range and height trajectory performance does not appear to be impaired by this sideslip rotation.

4.3.1 Event TIMES

Figures F-1 through F-7 (3 percentile dummy) and Figures F-8 through F-14 (98 percentile dummy) in Appendix F show the variation of the test event times as a function of the horizontal velocity at ejection for the NWC sled tests. Since the simulation times for Rocket Ignition and Rocket

APPROXIMATE ACTUAL SEAT/OCCUPANT ORIENTATIONS

TEST		1	2	3	4	5	6	7	8
Target ejection velocity	KEAS	0	225	0	225	435	435	600	600
Percentile Dummy	%	98	98	3	3	3	98	3	98
Pitch at Rocket ignition	DEG	10	20	10	20	30	30	40	50
Roll at Rocket ignition	DEG	0	0	0	0	0	0	0	0
Sideslip at Rocket ignition	DEG	0	0	0	0	0	0	0	0
Pitch at Rocket burnout	DEG	-45	-60	-45	-10	0	10	-45	-60
Roll at Rocket burnout	DEG	45	-45	-30	-10	30	30	-45	-45
Sideslip at Rocket burnout	DEG	45	135	60	160	-180	180	225	225

TABLE 4-4

Burnout are calculated by the ICARUS program they will be very slightly different than the test values. However, all of the other event times of the simulation, except for seat/occupant separation, will match the test times. The shape of the comparison graphs will be influenced by the variations of a particular event time. This is especially evident for the 3 percentile dummy simulation curves which are distorted after the drogue parachute is fully inflated, due to the anomalous main parachute pack opening time for test number 5. This time is not consistent with the magnitude and trends exhibited by the other tests, but it was used in the simulation in order to demonstrate the capability of the ICARUS program to accurately duplicate a trajectory with an anomaly at some event. Since only four points are available to define the simulation curves, they are of an arbitrary shape and they may vary if intermediate ejection velocities become available.

4.3.2 Horizontal Trajectory Performance

Graphs illustrating the comparison of the horizontal (down-range positive) distance and velocity test and simulation data are provided in Appendix F by Figures F-15 through F-21 (3 percentile dummy, horizontal distance), Figures F-22 through F-28 (98 percentile dummy, horizontal distance), Figures F-29 through F-35 (3 percentile dummy, horizontal velocity), and Figures F-36 through F-42 (98 percentile dummy, horizontal velocity).

The simulation distances are usually less than the actual test values. This difference would be alleviated had it been possible to use the reported wind data for the ICARUS program predictions and if the test

ground speeds were available. The horizontal distance and horizontal velocity trends show good agreement between the simulation and the actual test data, except for the two suspect 98 percentile dummy tests (tests 6 and 8). These tests show consistent deviations from the predicted horizontal velocity trends after rocket ignition has occurred. The deviation in horizontal distance for these two tests is not as apparent due to the scale of the graphs. A possible explanation for the decreased horizontal performance of these suspect tests can be made by the larger than predicted catapult tube bending which occurred during these two tests. This resulted in a seat/occupant orientation in which the rocket thrust had a larger component acting opposite to the down-range direction of motion.

4.3.3 Vertical Trajectory Performance

Graphs illustrating the comparison of the vertical (up is positive) distance and velocity for test and simulation data are contained in Appendix F by Figures F-43 through F-49 (3 percentile dummy, vertical distance), Figures F-50 through F-56 (98 percentile dummy, vertical distance), Figures 57 through F-63 (3 percentile dummy, vertical velocity) and Figures F-64 through F-70 (98 percentile dummy, vertical velocity).

The simulation distance and vertical velocity trends show good agreement with the actual test values, except for tests 6 and 8. These two tests show a lower vertical distance and velocity than would be expected from the simulation and the trends from the other tests. Again, this degraded performance can be accounted for by the fact that the actual

catapult tube bending for these tests is greater than that predicted by ICARUS. The plastic deforamtion of the catapult tubes may have impaired the performance of the catapult and also resulted in the seat/occupant being pitched too far back to achieve optimum trajectory performance during the rocket burn phase.

4.3.4 Lateral Trajectory Performance

A comparison of the lateral (off-range is positive to the right, facing forward) distance and velocity for both simulation and test data is presented in Appendix F by Figures F-71 through F-77 (3 percentile dummy, lateral distance), Figures F-78 through F-84 (98 percentile dummy, lateral distance), Figures F-85 through F-91 (3 percentile dummy, lateral velocity), and Figures F-92 through F-98 (98 percentile dummy, lateral velocity). Since it is not possible to account for the large actual test sideslip rotations during the rocket burn phase, the simulation data may not agree with the test data. However, since the magnitude of the test sideslip rotation is less at the low ejection velocities, the predicted and actual test data agree well for these cases. Conversely, the greatest sideslip rotation occurs at the higher ejection velocities and the predicted and actual test data show the worst agreement for those cases. The 600 KEAS tests for both the 3 and 98 percentile dummies show a small positive and a small negative divergence, respectively, even though the ejection seat is designed to diverge in a negative direction at all times.

4.3.5 Peak Trajectory Performance

Figures F-99 and F-100 in Appendix F contain graphs comparing the simulation and test vertical and horizontal distances at maximum trajectory height. These graphs show excellent agreement for the height and good agreement for the down-range comparison. The agreement between the simulation and test data for the down-range distance would have been better had it been possible to include the reported winds and the test ground speeds in the simulation. Again, the largest deviations for the down-range and vertical distance comparisons occur in tests 6 and 8.

4.4 Conclusions

Graphs of the simulation and test trajectory data for each condition tested at NWC are contained in Appendix G. These graphs, along with the analysis provided by section 4.3, illustrate the good agreement between the simulation and the test data. This agreement holds true for both magnitude and trends and verifies the capability of the ICARUS program to accurately simulate the performance of an ejection seat over a full range of ejection conditions. The availability of more accurate and definitive test data would have improved the accuracy of the simulation, since the trajectory of an ejection seat hinges on several key initial parameters, which are discussed in the following paragraphs.

The parameters required by the ICARUS program vary from items of major importance, which require accurate determination, to items of relatively minor importance where approximations are adequate. Typical items of major importance include parameters such as the catapult and rocket thrust,

aerodynamic coefficients for the seat/occupant, weight and dimensions of the seat/occupant, the center of gravity location of the seat/occupant, and the position of the rocket relative to the seat. These items require relatively accurate determination and reporting in order for the ICARUS program to provide valid predictions. Given an accurate set of input parameters for a particular test or theoretical case, the ICARUS program will accurately simulate the ejection trajectory for those conditions.

4.4.1 Catapult and Rocket Thrust

Except for the aerodynamic forces, which only become predominant at the higher ejection velocities, the most important parameter in determining the trajectory performance of an ejection seat is the thrust generated by the catapult and the rocket. The simulation is based on a typical rocket thrust vs. time curve, which is assumed to be valid for all tests. The curve is adjusted to account for the actual test rocket burn time while keeping the total impulse the same as the typical curve. The catapult and rocket characteristics will vary due to ambient atmospheric conditions, ejection velocities, and manufacturing inaccuracies. Any variations in actual catapult and/or rocket thrust from the values used in the simulation will have a major effect on the accuracy of the predicted trajectory when compared to test data.

4.4.2 Seat/Occupant Center of Gravity

The position of the seat/occupant combined center of gravity must be known accurately in order to simulate the angular motion of the seat/

occupant during the catapult and rocket phases and to simulate the aerodynamic moments acting on the seat/occupant. Any errors in the center of gravity location will be reflected as an inaccurate simulation of the motion of the seat/occupant during the catapult and rocket phases, with consequent inaccuracies in the predicted trajectories.

4.4.3 Catapult Tube Deflection

The catapult tube deflection equations were derived empirically in an attempt to model the behavior of other Martin-Baker type catapults. Since the amount of catapult tube bending can make several degrees difference in the pitch attitude of the seat/occupant at rocket ignition, the trajectory may vary appreciably as a function of the catapult tube deflection. Based on films of the F-18A tests at NWC, the simulated deflections differ in some cases from the actual (estimated) deflections. This is especially true of the 600 KEAS cases where plastic deformation occurred. Deflection of the catapult tube is caused by the interaction of the seat/occupant and the guide rails during the catapult phase, and by the aerodynamic forces and moments acting on the seat/occupant. For 0 KEAS tests, the aerodynamic forces and moments are negligible and the test films illustrate the catapult tube bending forward approximately 10° from its initial position, due to the effect of the seat/occupant and guide rails interaction. For the 600 KEAS tests, the aerodynamic forces and moments are predominant and the test films show the catapult tube bending back about 20° from its initial position with the catapult tube retaining this deformation.

4.4.4 Aerodynamic Forces

Since the aerodynamic forces are the dominant force acting on the seat/occupant during the higher velocity ejection tests, the good agreement between the simulation and test data for the 3 percentile dummy 435 and 600 KEAS tests verifies that the set of seat/occupant aerodynamic coefficeints used by the ICARUS program is representative of this seat/occupant combination. Therefore, it is felt that the ICARUS program can accurately simulate the aerodynamic forces acting on a seat/occupant for the full range of velocities demonstrated by these tests as long as the seat/occupant maintains its configurational integrity during the ejection.

4.4.5 Drogue and Main Parachutes

The trajectory performance during the drogue and main parachute phases of the ejection shows good agreement between the simulation and test data. The parachute equations of the ICARUS program model a typical parachute and do not have the capability to exactly duplicate the behavior of the GQ Aeroconical Canopy of the main parachute used in the F-18A Escape System. This parachute has a steerable capability and for this reason no attempt was made to compare the simulation results with test data after main parachute full inflation. The ICARUS program simulates the seat/occupant separation as occurring shortly after parachute riser line stretch, while the test data for the 0 KEAS cases indicates that it occurs later. Except for this discrepancy, the simulation very closely matches the ejection trajectory during the drogue and main parachute phases up to main parachute full inflation. Beyond this point, the simulation cannot predict the random descent trajectory that may be caused by the steerable capability of the Aeroconical Canopy.

5.0 UTILITY PROGRAMS

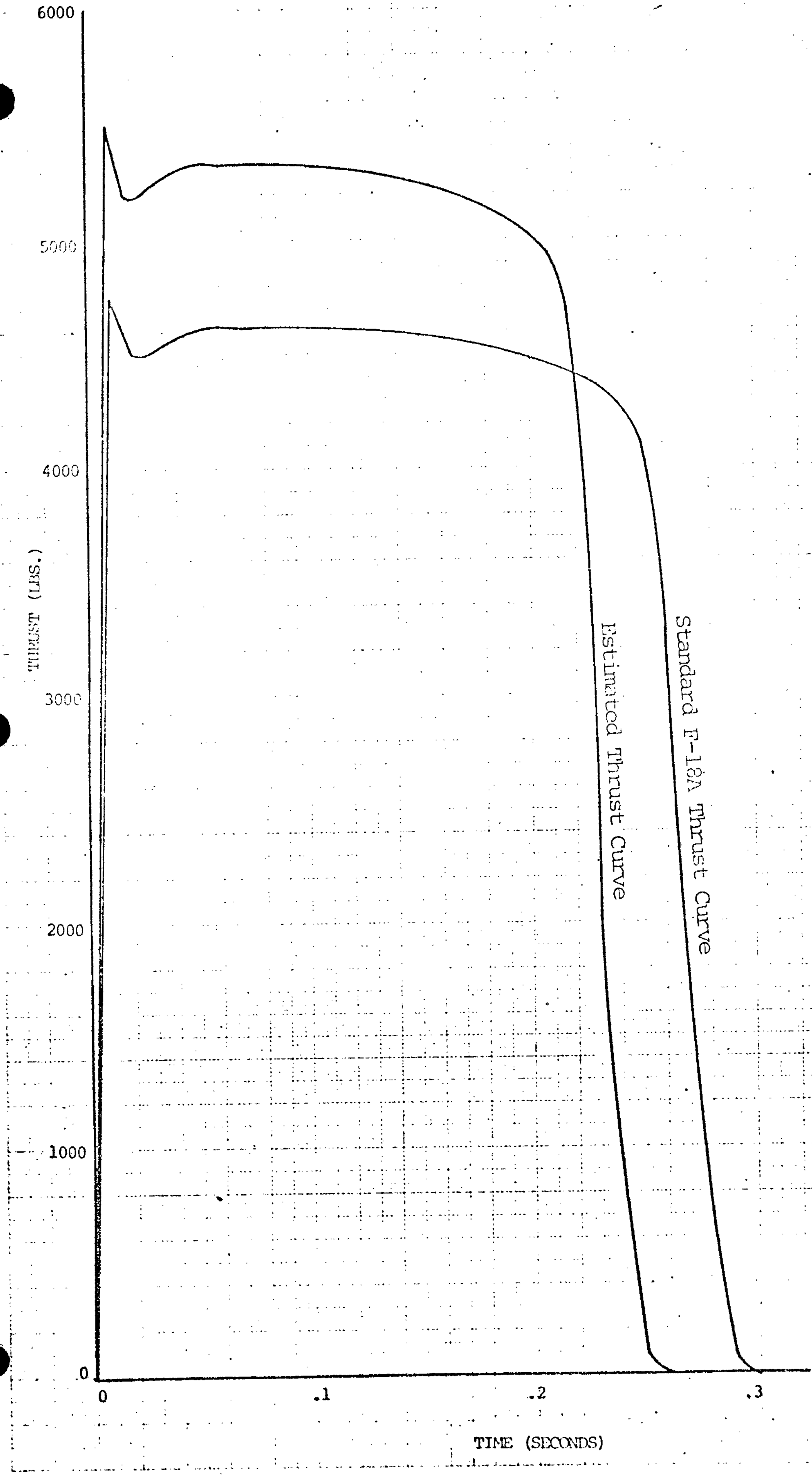
To simplify the process of making ICARUS runs, CSC developed and implemented 2 utility programs: COMPARE and THRUST. COMPARE compares each variable in up to 10 ICARUS input files, thus making it easier to verify the inputs when making a series of runs. THRUST calculates the actual rocket thrust vs. time curve to correspond to an input rocket burn time, keeping the total impulse the same as an established average curve. In addition, CSC combined the capabilities of various versions of the ICARUS plotting program into a single version (ICAPLTS) with some additional features. Each of these three programs is discussed below.

5.1 ICAPLTS

CSC consolidated various versions of the program used to generate plots from ICARUS output and NWC test data into one version with some modifications. All previous versions have been purged to eliminate confusion. The file containing the NWC test data for the 8 F-18A sled tests has been reformatted to the same format as the data output by ICARUS. Examples of how to use the 4 basic options implemented in the plotting program are contained in Appendix H, along with samples of the plots generated.

5.2 THRUST

Based on an average rocket thrust time curve, THRUST will recalculate the actual thrust curve, keeping total impulse constant, to correspond to an input rocket burn time. Figure 5-1 shows a plot of the average thrust curve used in ICARUS for F-18A runs (based on a .3 second burn time)



6000
5000
4000
3000
2000
1000
0
THRUST (LBS.)
0
.1
.2
.3
TIME (SECONDS)
Estimated Thrust Curve
Standard F-18A Thrust Curve

Figure 5-1

and the recalculated thrust curve corresponding to a .26 burn time (from NWC F-18A sled test #2). Figure 5-2 shows how to use the THRUST program. Before running the program, the standard thrust table, number of points and new burn time should be set up in the source code as indicated on the program listing found in Appendix I. Appendix I also contains a sample of the output generated by THRUST.

5.3 COMPARE Program

The COMPARE program was developed and implemented to simplify the process of verifying the input files for runs made with the ICARUS Simulation Program. COMPARE will read up to 10 ICARUS input files and output them as shown in Appendix J. There is also an option in the program to calculate and print the average of each input variable. Figure 5-3 gives a description of how to use the COMPARE program. Before running COMPARE, the number of input files to be read (NTAPES) and the flag controlling the generation of average output (IAVG) must be set appropriately in the source program where indicated on the listing. The program listing can be found in Appendix J.

```
/get,thrust
/assign,ms,output
MS, ASSIGNED TO OUTPUT.
/ftn,i=thrust,r=3
      .788 CP SECONDS COMPILATION TIME
/lgo
STOP
/dispose,output=pr/ei=cd8902
```

FIGURE 5-2

```
/get,tape1=inf181a,tape2=inf182a,tape3=inf183a,tape4=inf184a
/get,tape5=inf185a,tape6=inf186a,tape7=inf187a,tape8=inf188a
/get,compare
/assign,ms,output
MS, ASSIGNED TO OUTPUT.
/ftn4,i=compare,r=3
      .902 CP SECONDS COMPILATION TIME
/lgo
     END  COMPARE
     2.533 CP SECONDS EXECUTION TIME
/dispose,output=pr/ei=cd8902
```

FIGURE 5-3

APPENDIX A

F-18A ESCAPE SYSTEM PERFORMANCE STUDY

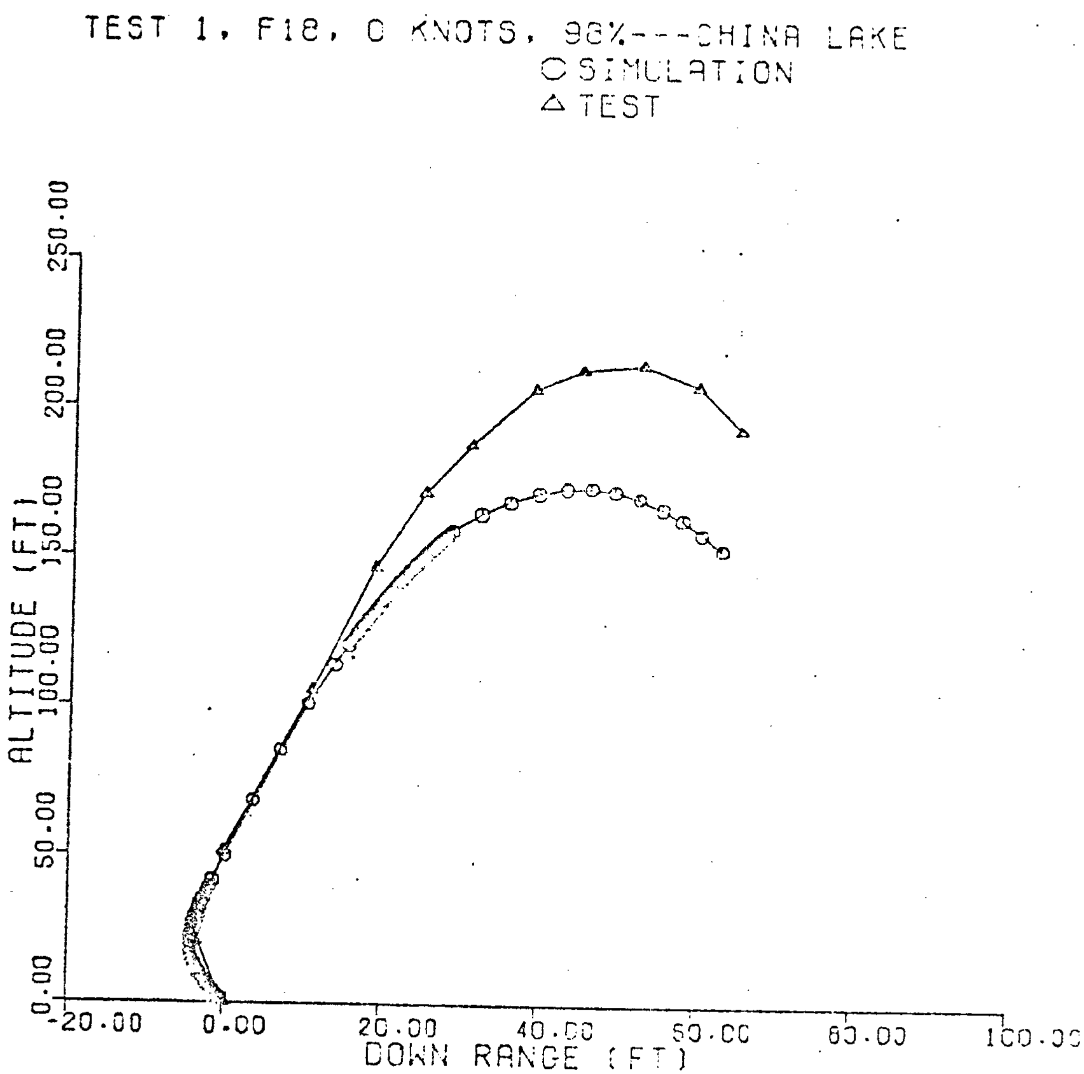

TEST 1, F18, 0 KNOTS, 98%---CHINA LAKE
○ SIMULATION
△ TEST
ALTITUDE (FT)
0.00
50.00
100.00
150.00
200.00
250.00
-20.00
0.00
20.00
40.00
60.00
80.00
100.00
DOWN RANGE (FT)

Figure-A-1

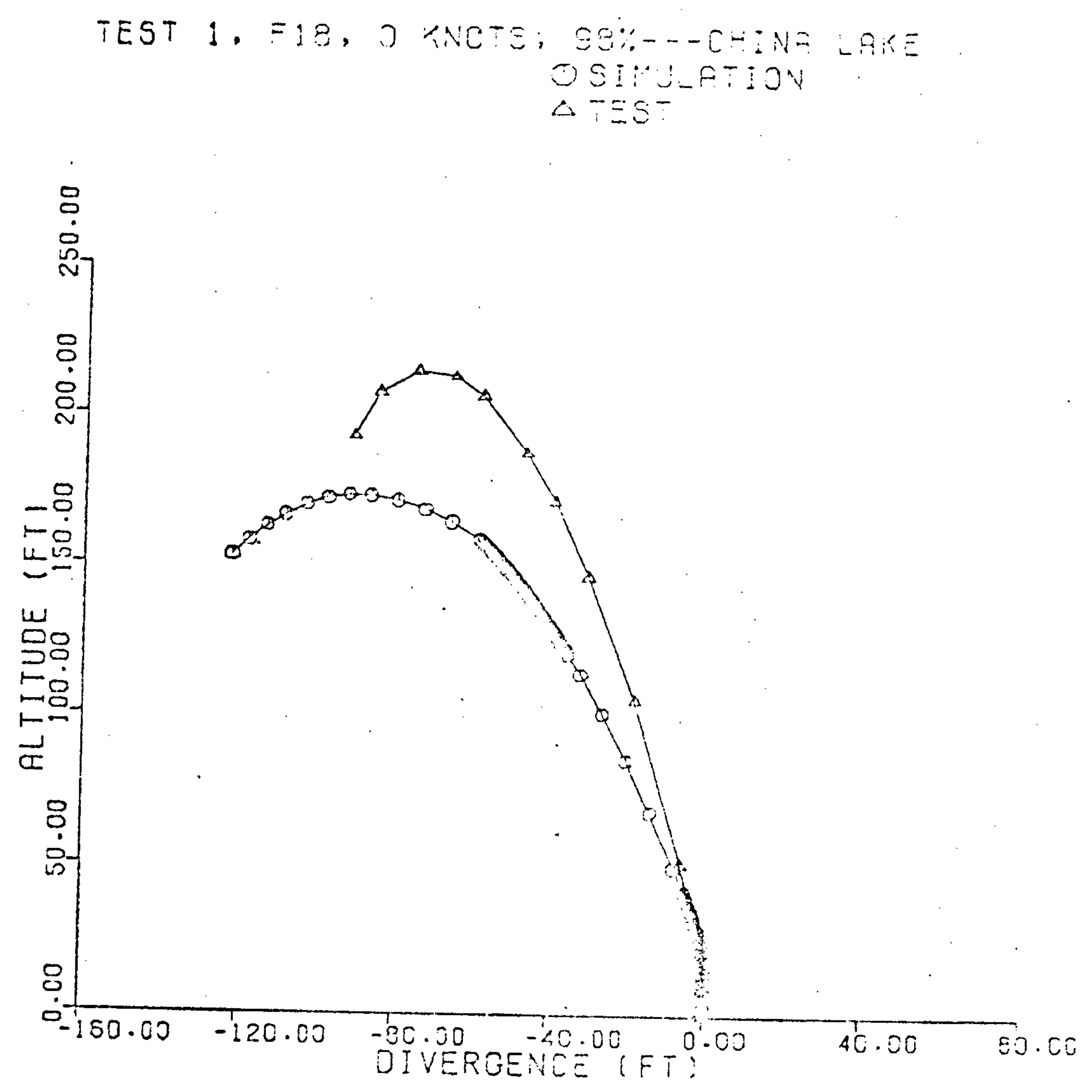

TEST 1, F18, 0 KNOTS, 98%---CHINA LAKE
○ SIMULATION
△ TEST
ALTITUDE (FT)
250.00
200.00
150.00
100.00
50.00
0.00
-160.00
-120.00
-80.00
-40.00
0.00
40.00
80.00
DIVERGENCE (FT)

Figure-A-2

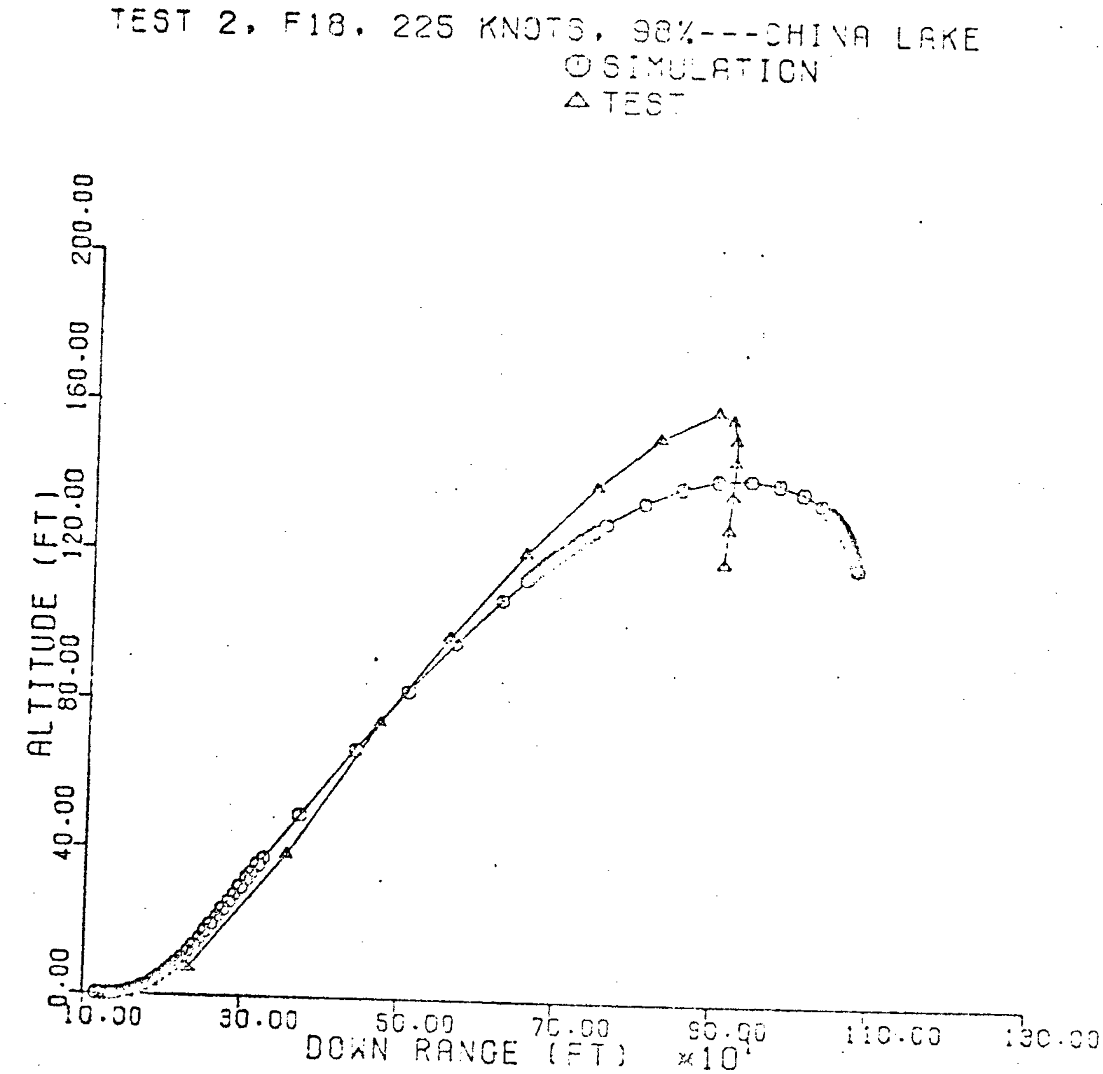

TEST 2, F18, 225 KNOTS, 98%---CHINA LAKE
⊙ SIMULATION
△ TEST
ALTITUDE (FT)
0.00
40.00
80.00
120.00
160.00
200.00
10.00
30.00
50.00
70.00
90.00
110.00
130.00
DOWN RANGE (FT) ×10[1]

Figure-A-3

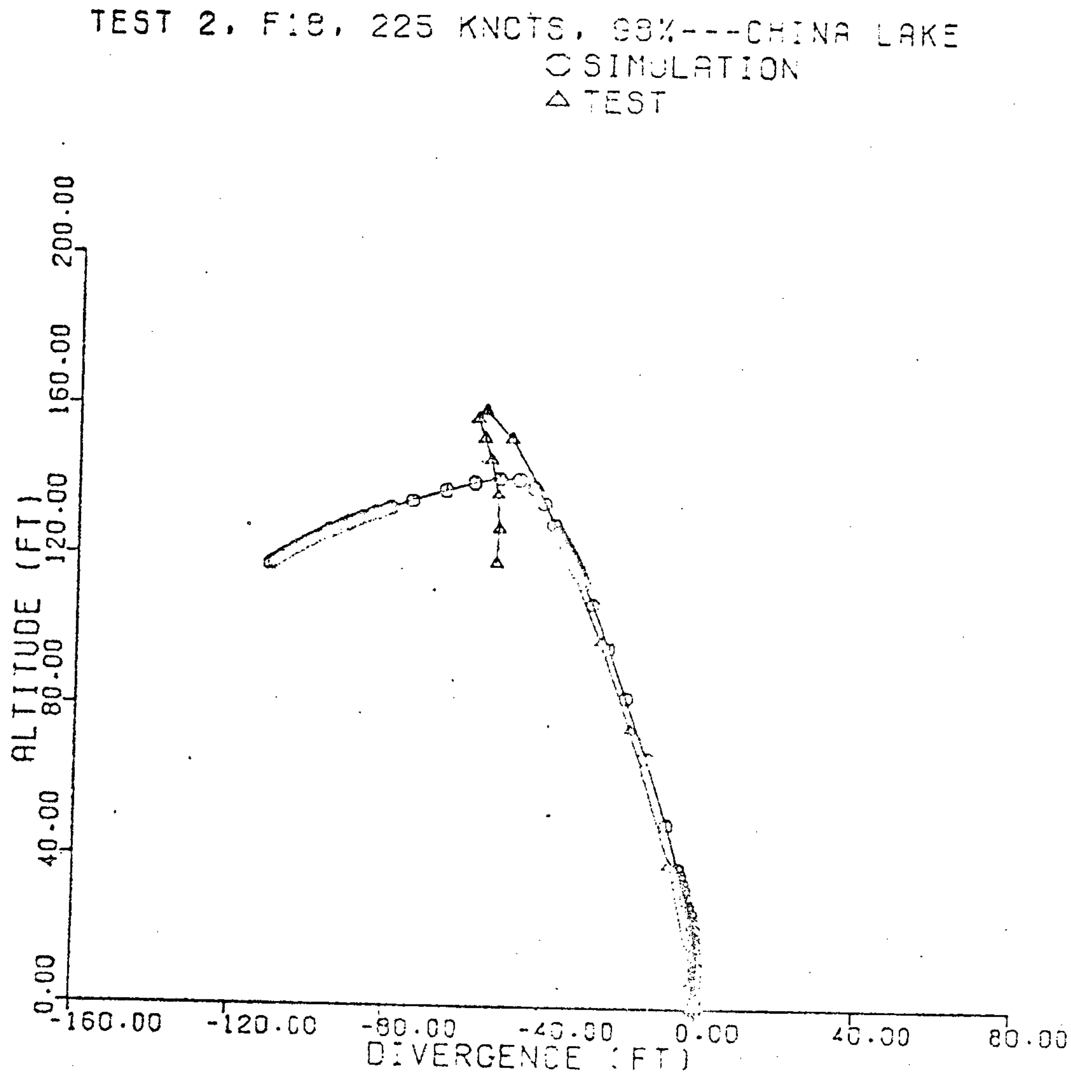

TEST 2, F18, 225 KNOTS, 98%---CHINA LAKE
SIMULATION
TEST
ALTITUDE (FT)
0.00
40.00
80.00
120.00
160.00
200.00
DIVERGENCE (FT)
-160.00
-120.00
-80.00
-40.00
0.00
40.00
80.00

Figure-A-4

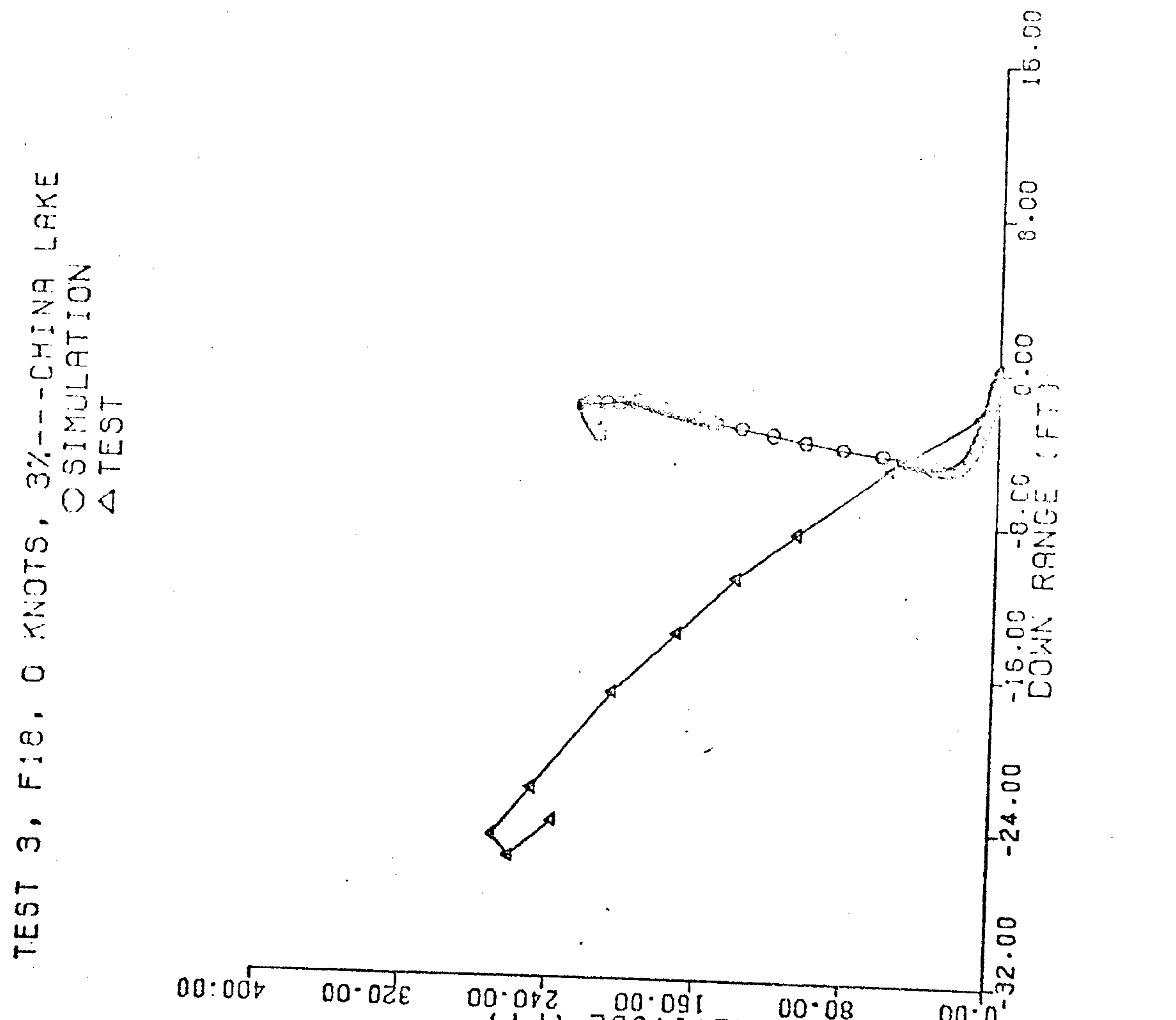
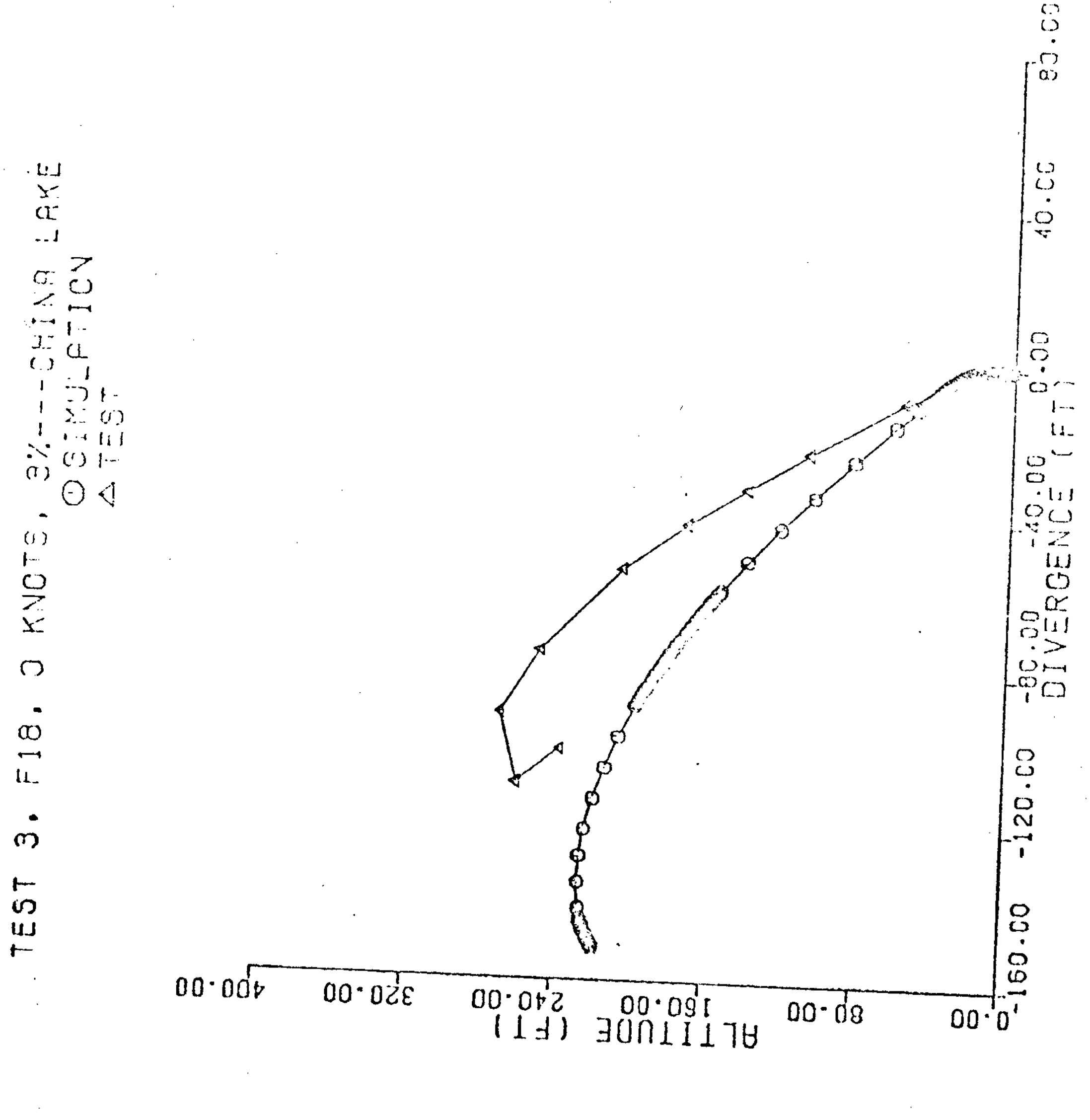

TEST 3, F18, 0 KNOTS, 3%---CHINA LAKE
○ SIMULATION
△ TEST
ALTITUDE (FT)
0.00
80.00
160.00
240.00
320.00
400.00
DOWN RANGE (FT)
-32.00
-24.00
-16.00
-8.00
0.00
8.00
16.00

Figure-A-5



TEST 3. F18, 0 KNOTS, 3%---CHINA LAKE
SIMULATION
TEST
ALTITUDE (FT)
0.00
80.00
160.00
240.00
320.00
400.00
DIVERGENCE (FT)
-160.00
-120.00
-80.00
-40.00
0.00
40.00
80.00

Figure-A-6

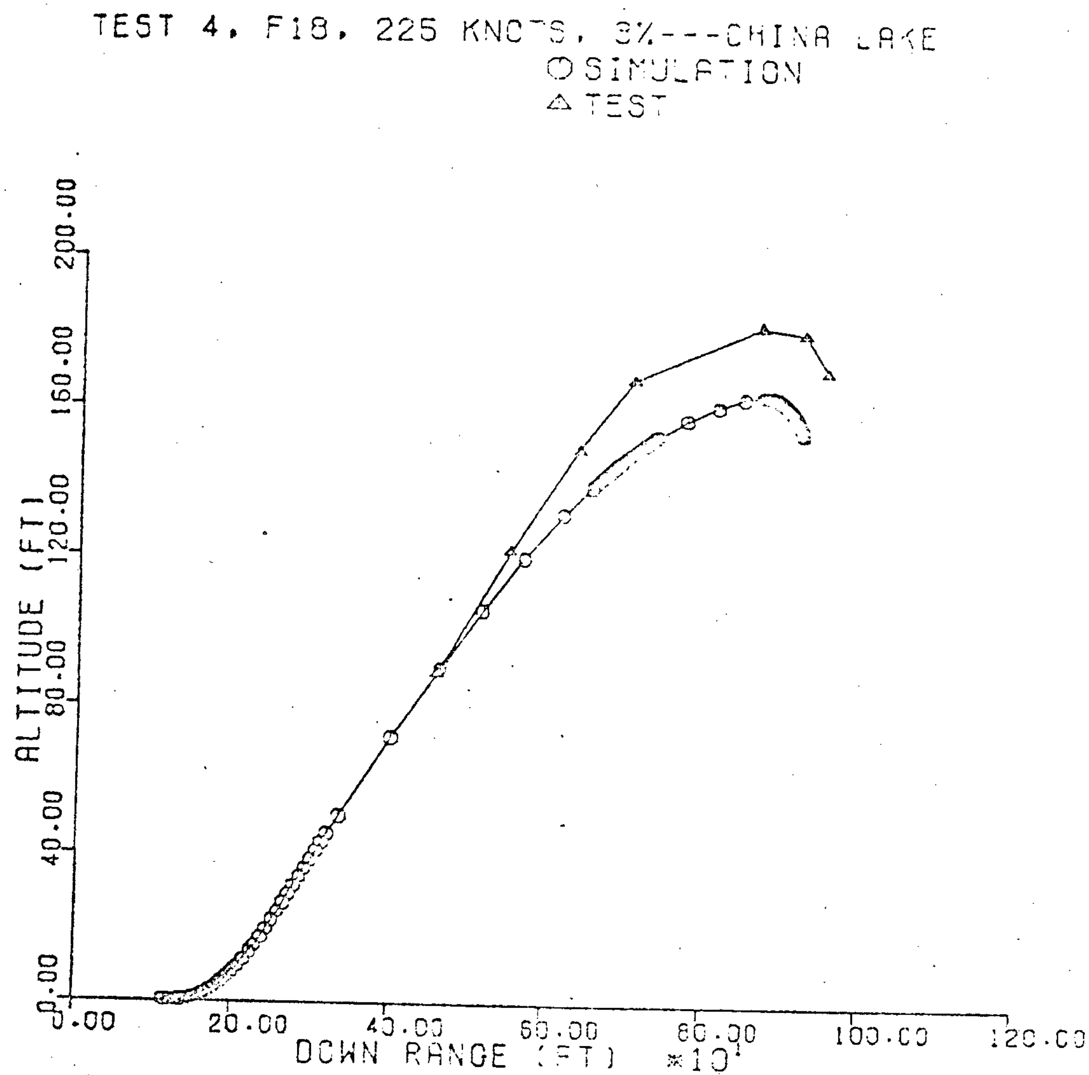

TEST 4, F18, 225 KNOTS, 3%---CHINA LAKE
○ SIMULATION
△ TEST
ALTITUDE (FT)
0.00
40.00
80.00
120.00
160.00
200.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
DOWN RANGE (FT) *10¹

Figure-A-7

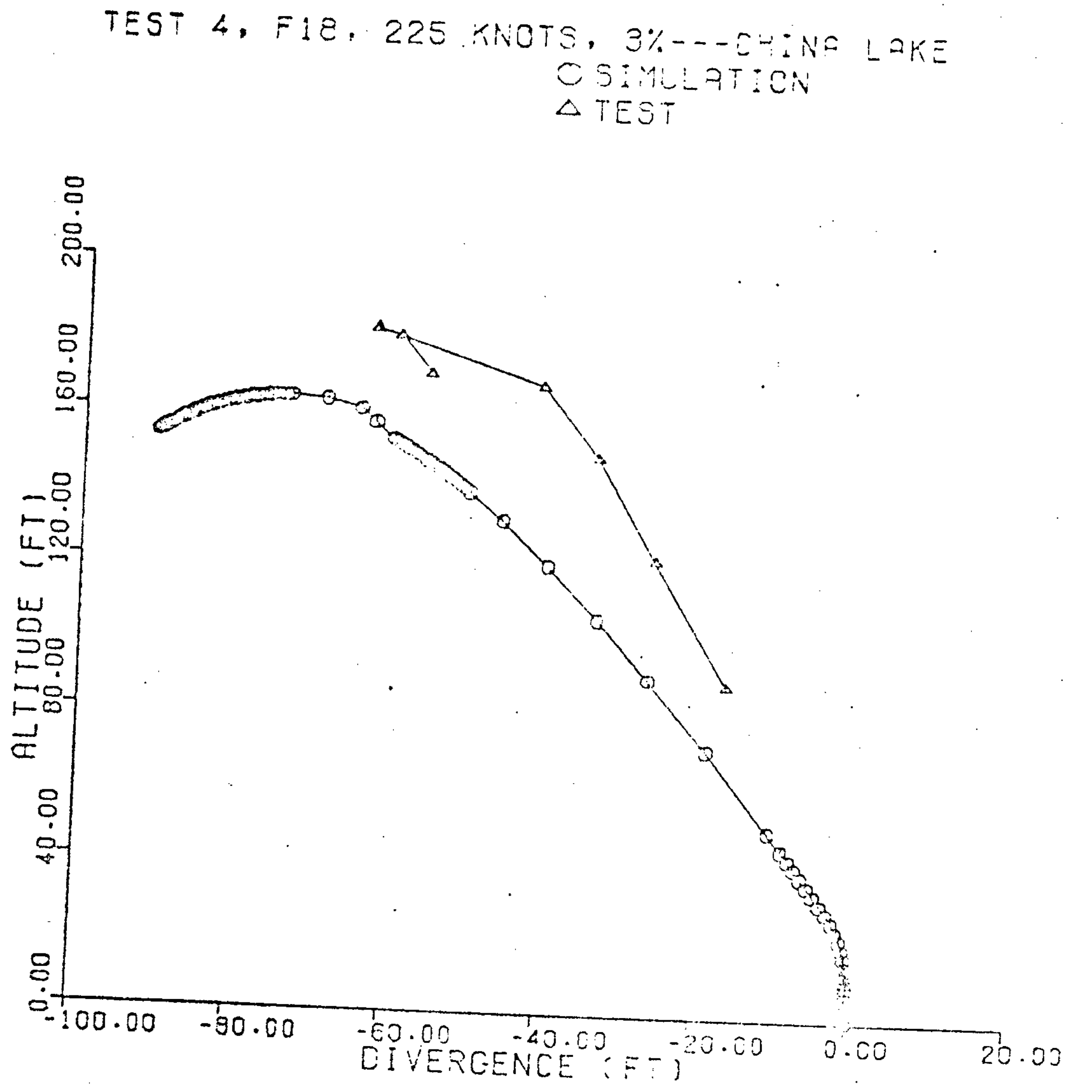

TEST 4, F18, 225 KNOTS, 3%---CHINA LAKE
○ SIMULATION
△ TEST
ALTITUDE (FT)
0.00
40.00
80.00
120.00
160.00
200.00
DIVERGENCE (FT)
-100.00
-80.00
-60.00
-40.00
-20.00
0.00
20.00

Figure A-8

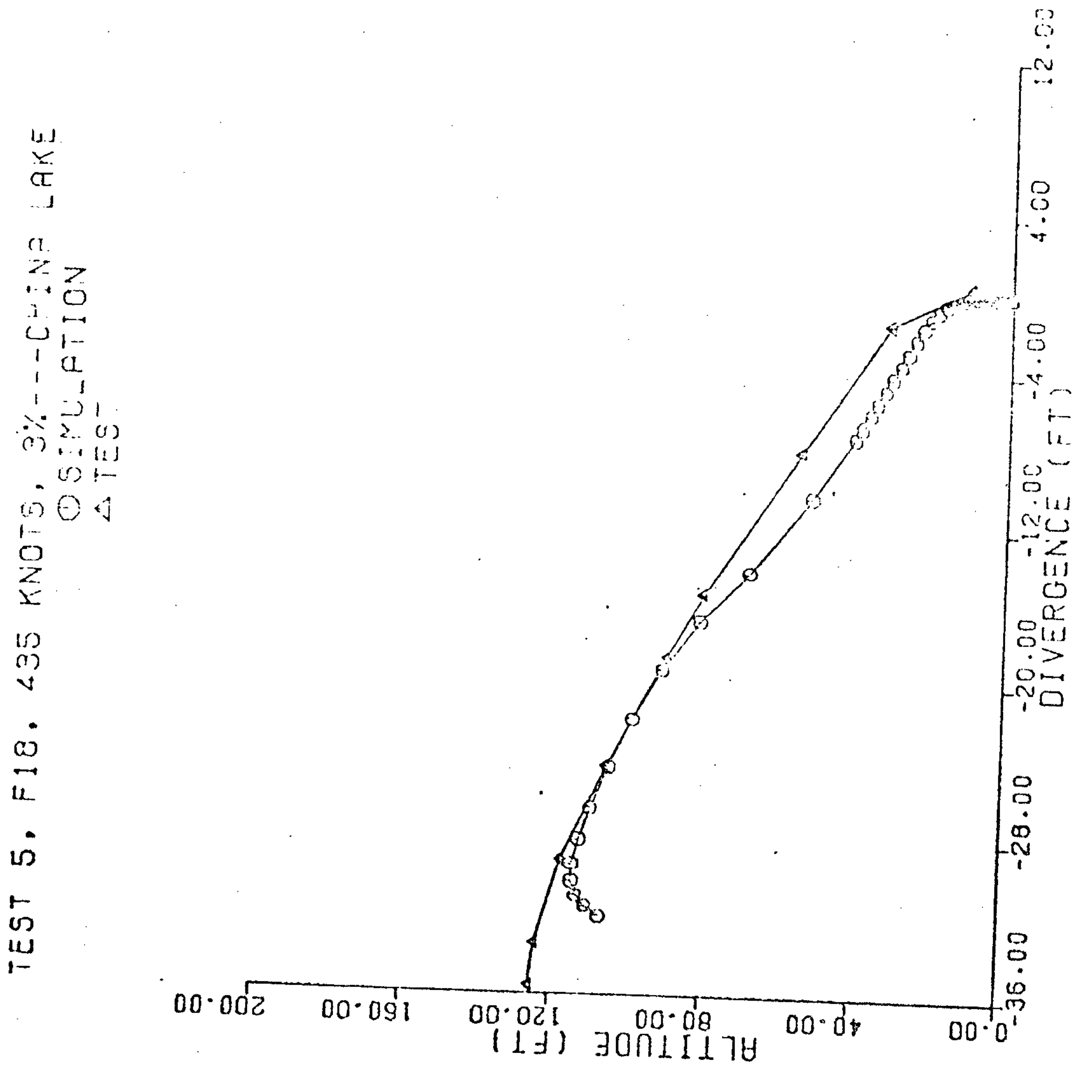

TEST 5, F18, 435 KNOTS, 3%---CHINA LAKE
SIMULATION
TEST
ALTITUDE (FT)
0.00
40.00
80.00
120.00
160.00
200.00
DIVERGENCE (FT)
-36.00
-28.00
-20.00
-12.00
-4.00
4.00
12.00

Figure A-9

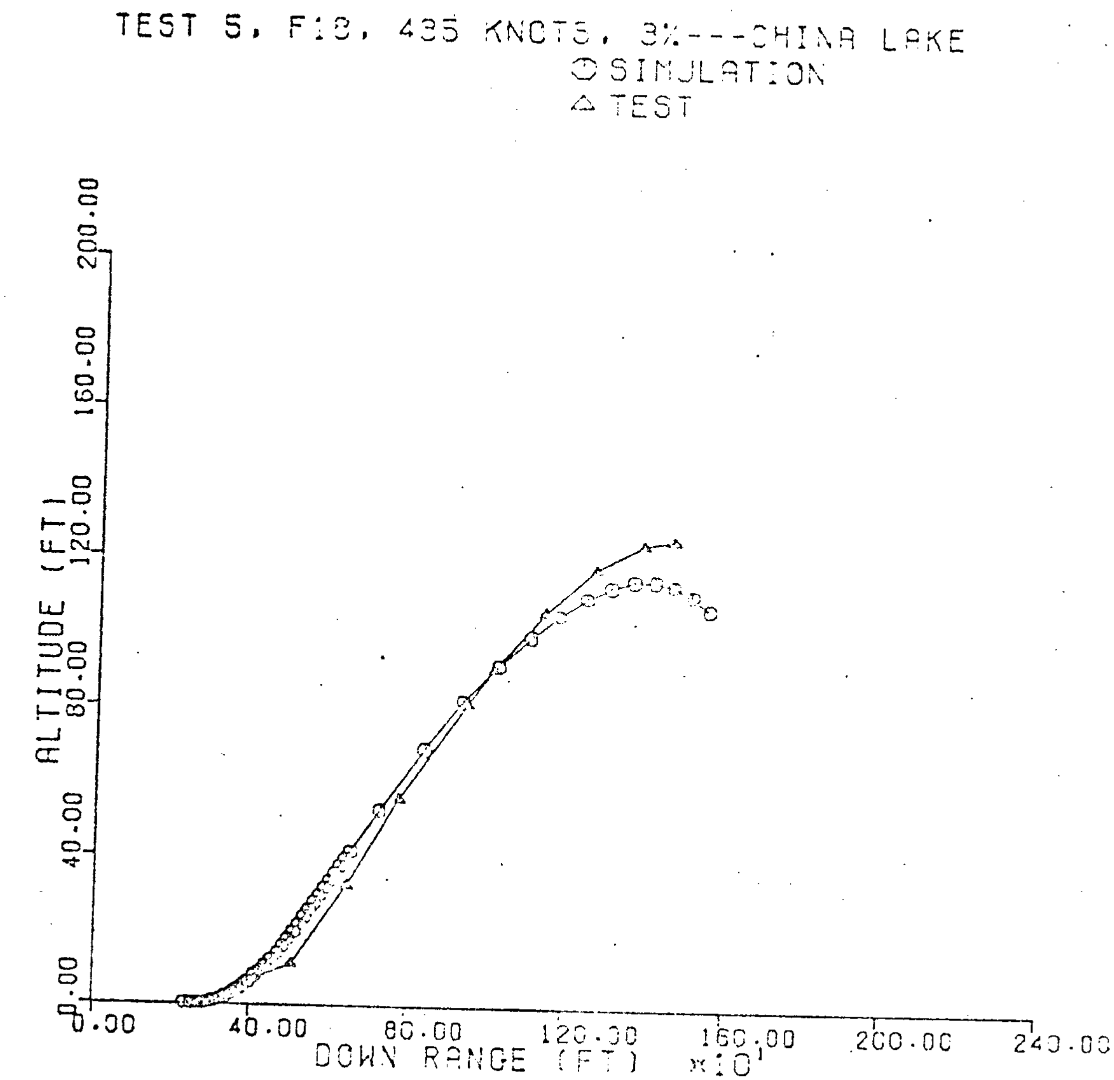

TEST 5, F18, 435 KNOTS, 3%---CHINA LAKE
SIMULATION
TEST
ALTITUDE (FT)
0.00
40.00
80.00
120.00
160.00
200.00
DOWN RANGE (FT) x10[1]
0.00
40.00
80.00
120.00
160.00
200.00
240.00

Figure A-10

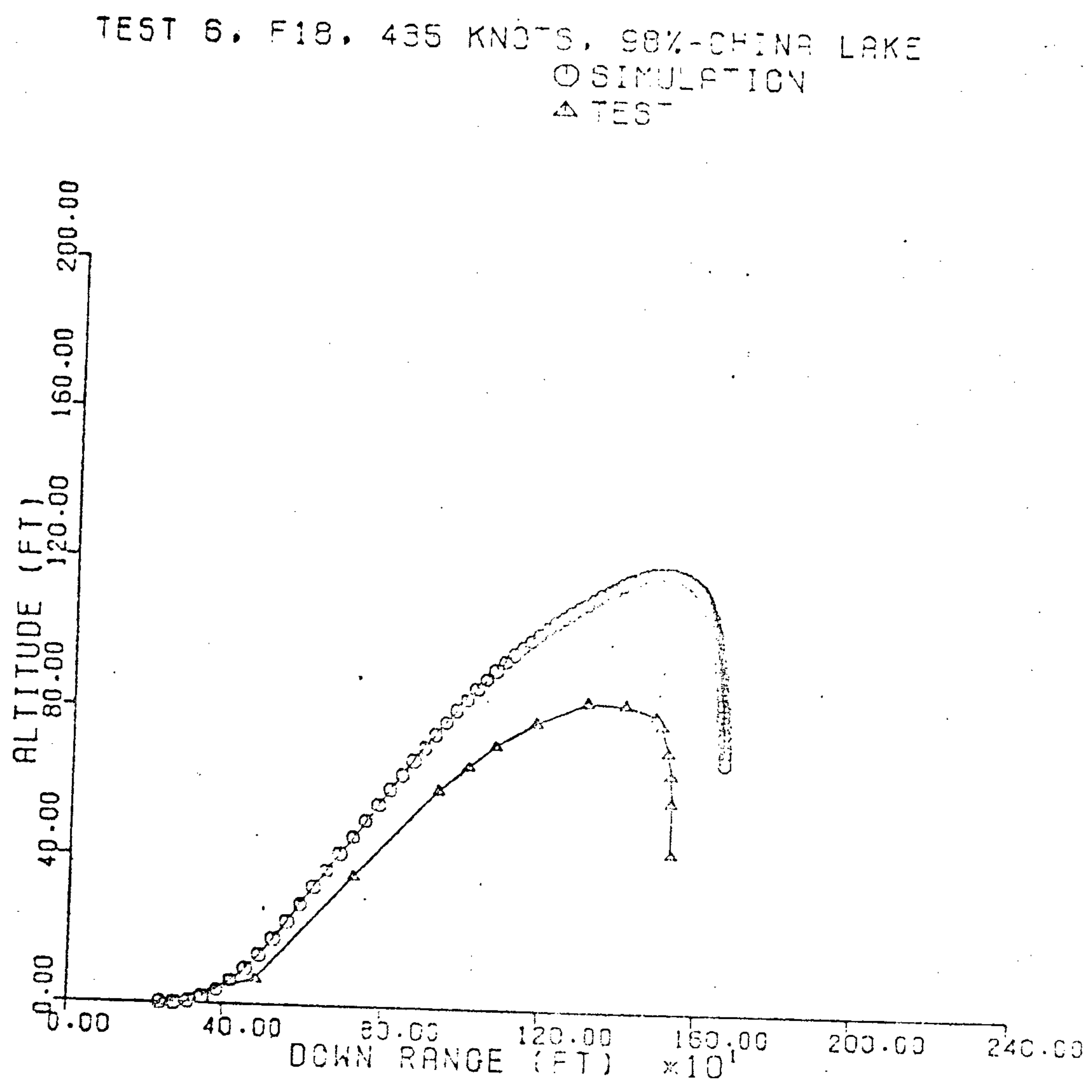

TEST 6, F18, 435 KNOTS, 98%-CHINA LAKE
SIMULATION
TEST
ALTITUDE (FT)
0.00
40.00
80.00
120.00
160.00
200.00
DOWN RANGE (FT) x10[1]
0.00
40.00
80.00
120.00
160.00
200.00
240.00

Figure A-11

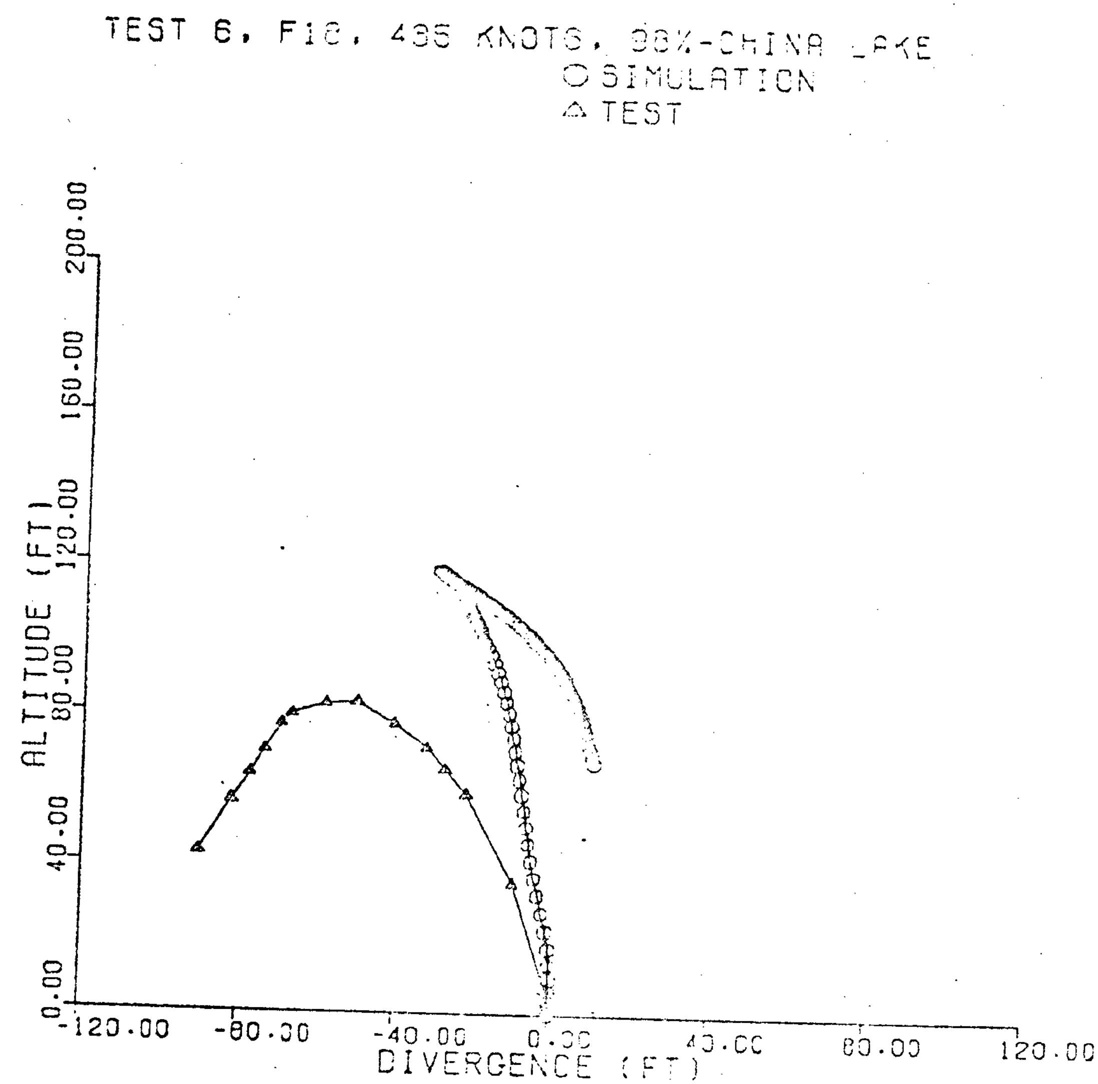

TEST 6, F18, 435 KNOTS, 98%-CHINA LAKE
SIMULATION
TEST
ALTITUDE (FT)
200.00
160.00
120.00
80.00
40.00
0.00
-120.00
-80.00
-40.00
0.00
40.00
80.00
120.00
DIVERGENCE (FT)

Figure A-12

TEST 7, F18, 600 KNOTS, 3%---CHINA LAKE

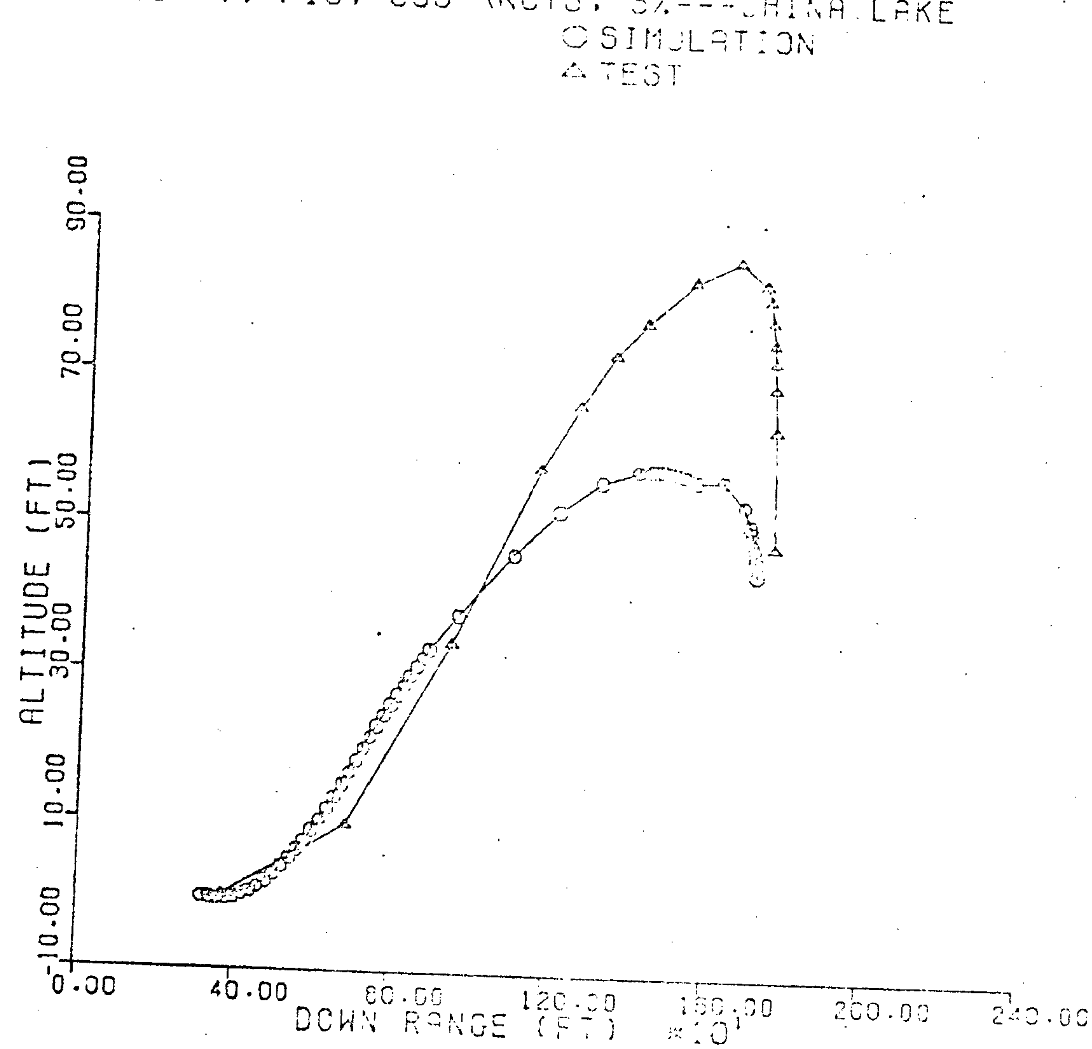
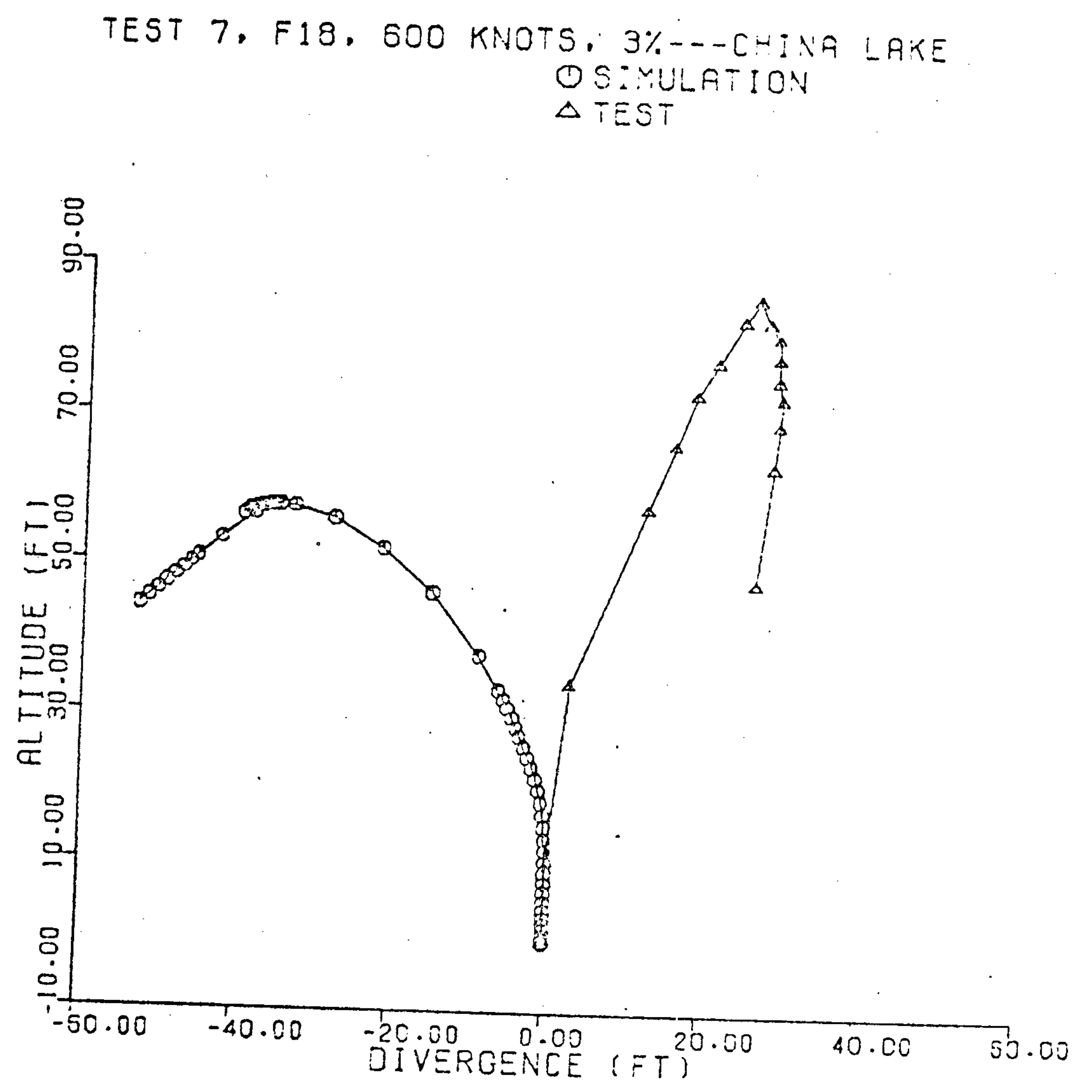


Figure A-13



TEST 7, F18, 600 KNOTS, 3%---CHINA LAKE
SIMULATION
TEST
ALTITUDE (FT)
90.00
70.00
50.00
30.00
10.00
-10.00
-60.00
-40.00
-20.00
0.00
20.00
40.00
60.00
DIVERGENCE (FT)

Figure A-14

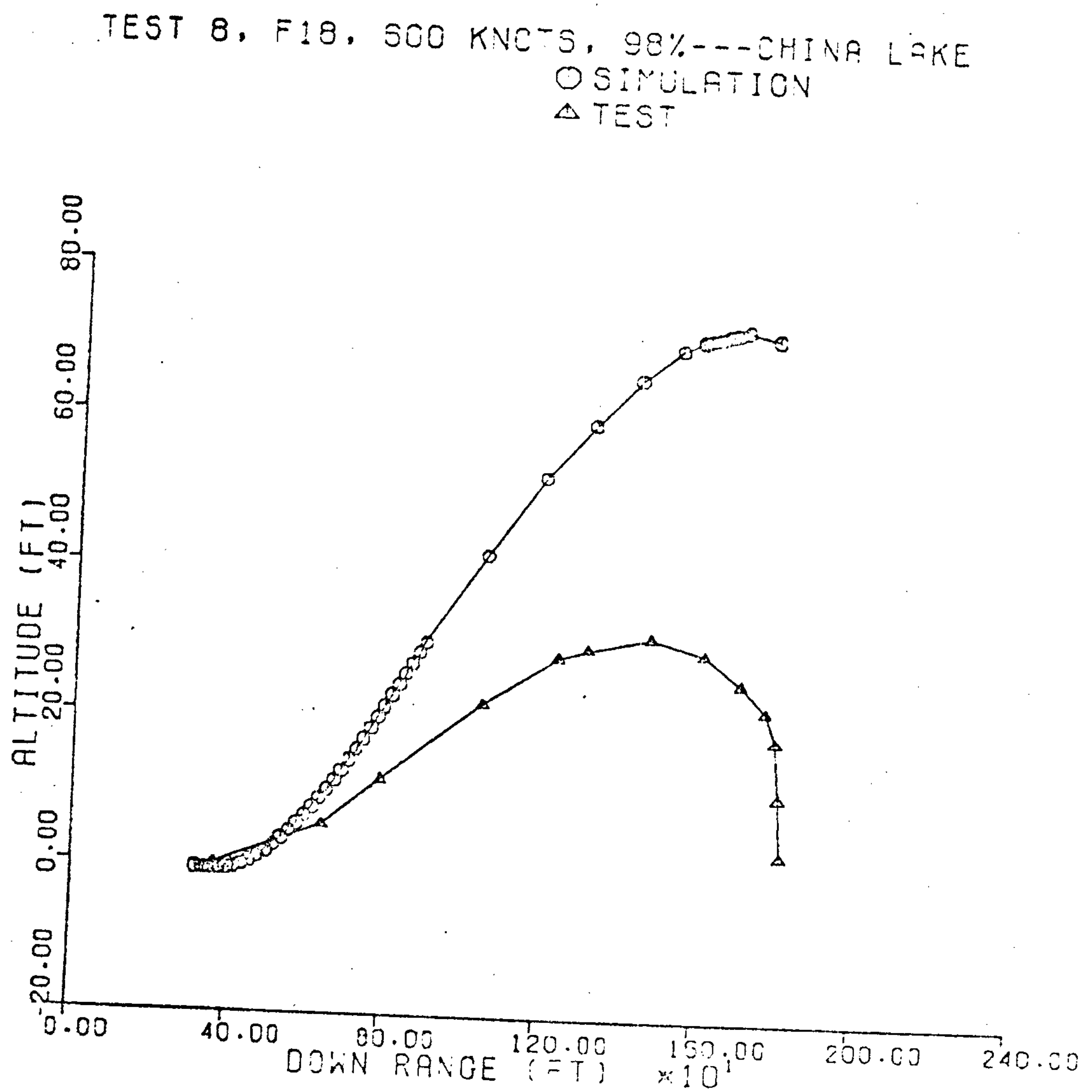

TEST 8, F18, 600 KNOTS, 98%---CHINA LAKE
SIMULATION
TEST
ALTITUDE (FT)
80.00
60.00
40.00
20.00
0.00
-20.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
DOWN RANGE (FT) ×10¹

Figure A-15

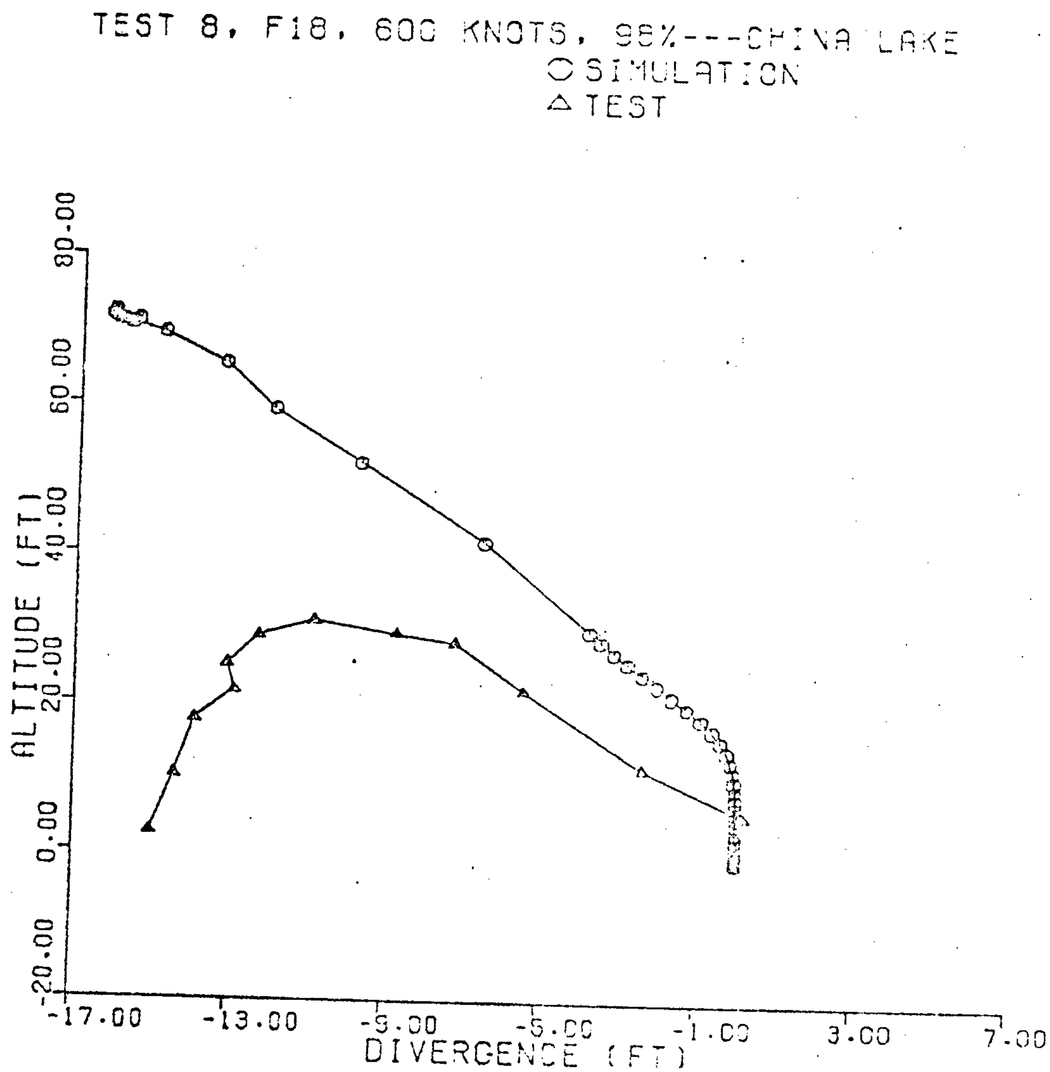

TEST 8, F18, 600 KNOTS, 98%---CHINA LAKE
SIMULATION
TEST
ALTITUDE (FT)
80.00
60.00
40.00
20.00
0.00
-20.00
-17.00
-13.00
-9.00
-5.00
-1.00
3.00
7.00
DIVERGENCE (FT)

Figure A-16

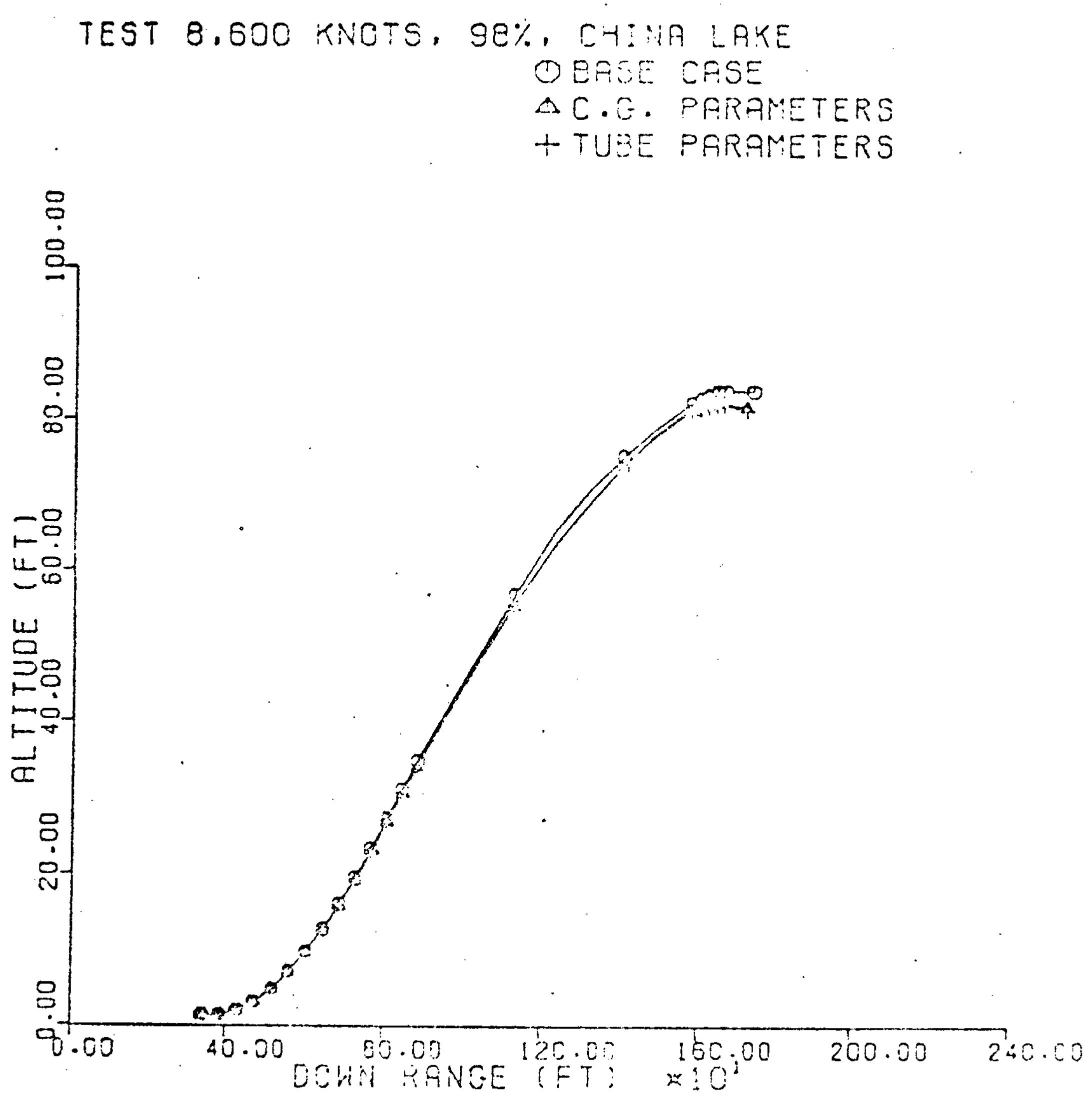

TEST 8.600 KNOTS, 98%, CHINA LAKE
BASE CASE
C.G. PARAMETERS
TUBE PARAMETERS
ALTITUDE (FT)
0.00
20.00
40.00
60.00
80.00
100.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
DOWN RANGE (FT) ×10[1]

Figure A-17

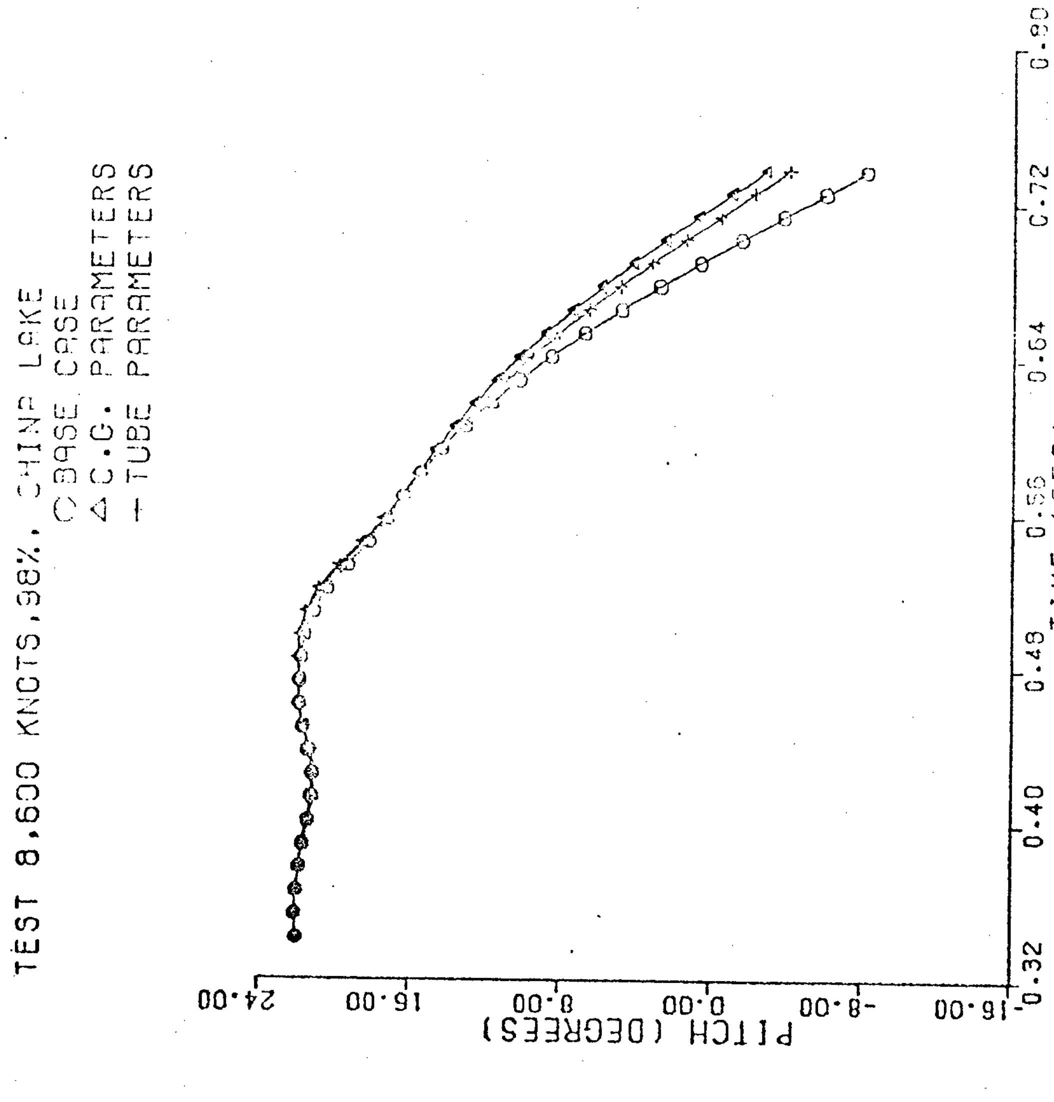
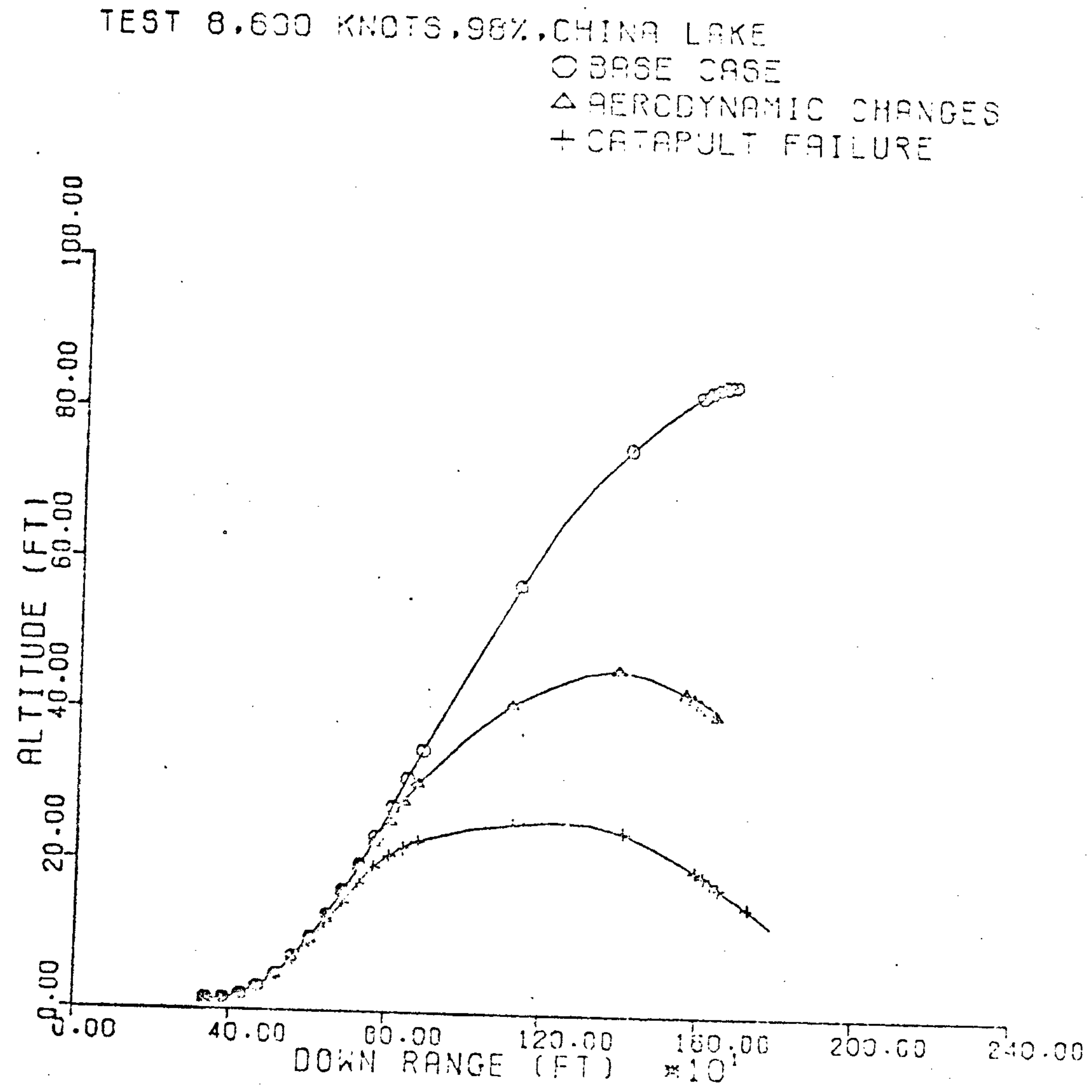

TEST 8.600 KNOTS,98%, CHINA LAKE
○ BASE CASE
△ C.G. PARAMETERS
+ TUBE PARAMETERS
PITCH (DEGREES)
24.00
16.00
8.00
0.00
-8.00
-16.00
TIME (SEC)
0.32
0.40
0.48
0.56
0.64
0.72
0.80

Figure A-18



TEST 8.600 KNOTS,98%,CHINA LAKE
BASE CASE
AERODYNAMIC CHANGES
CATAPULT FAILURE
ALTITUDE (FT)
0.00
20.00
40.00
60.00
80.00
100.00
DOWN RANGE (FT) *10[1]
40.00
80.00
120.00
160.00
200.00
240.00

Figure A-19

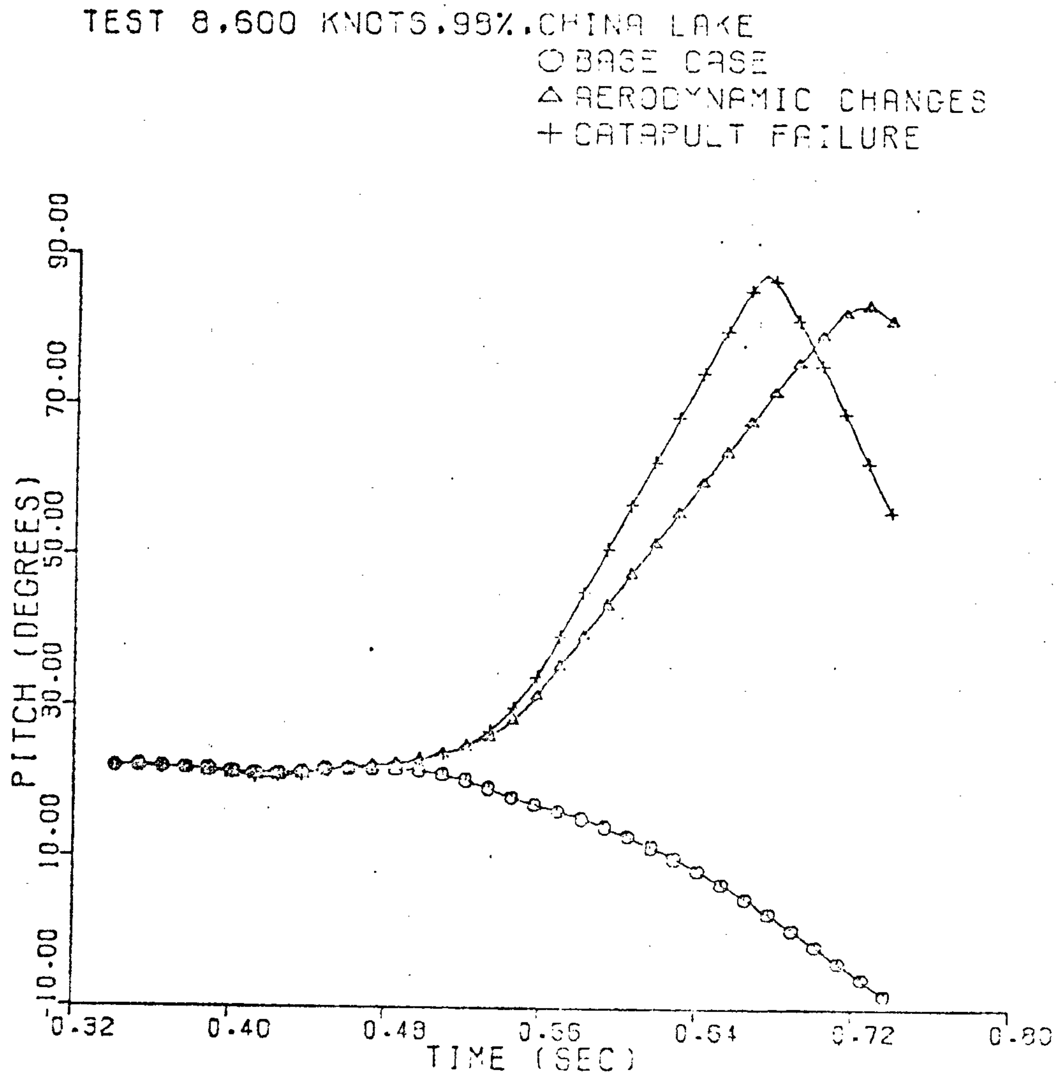

TEST 8,600 KNOTS,98%,CHINA LAKE
○ BASE CASE
△ AERODYNAMIC CHANGES
+ CATAPULT FAILURE
PITCH (DEGREES)
-10.00
10.00
30.00
50.00
70.00
90.00
0.32
0.40
0.48
0.56
0.64
0.72
0.80
TIME (SEC)

Figure A-20

PERFORMANCE TEST 1 - INITIAL CONDITIONS: 100 KNOTS 98 PERCENTILE
ALTITUDE: 22 FT SINK RATE: 40 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

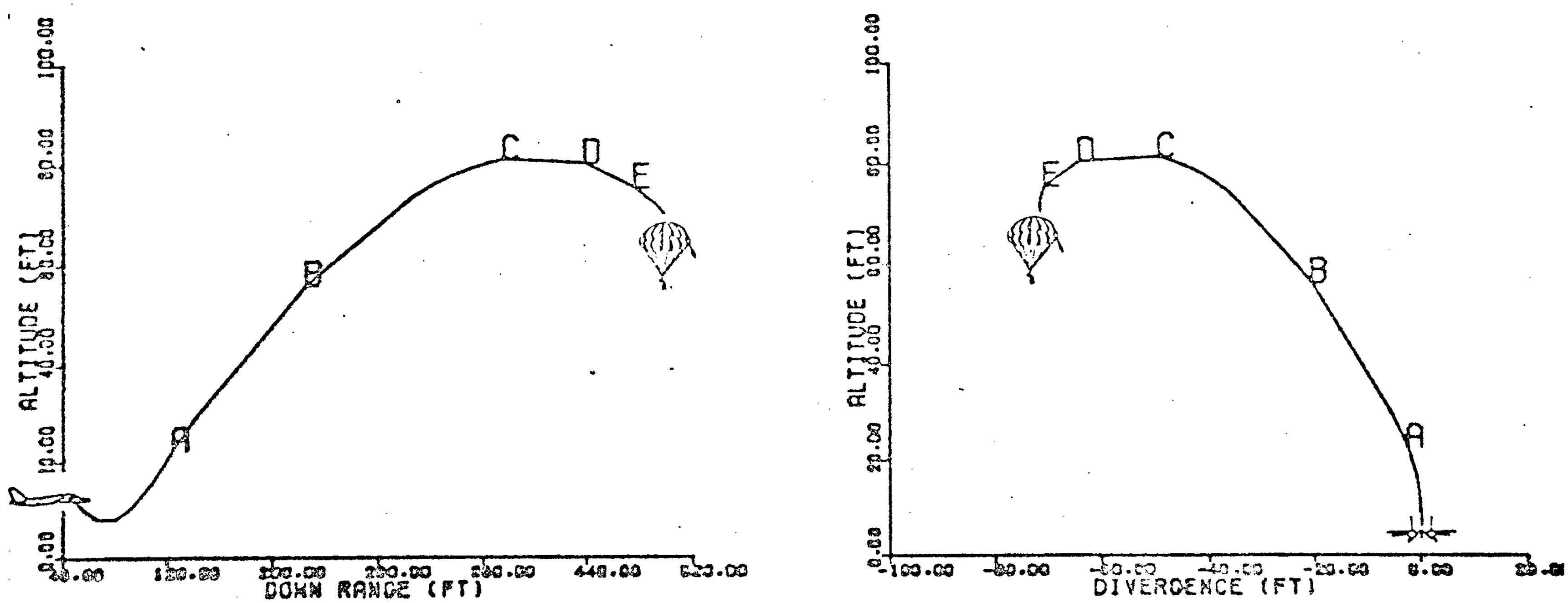


Figure A-21

PERFORMANCE TEST 2 - INITIAL CONDITIONS: 100 KNOTS 98 PERCENTILE
ALTITUDE: 45 FT SINK RATE: 83 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

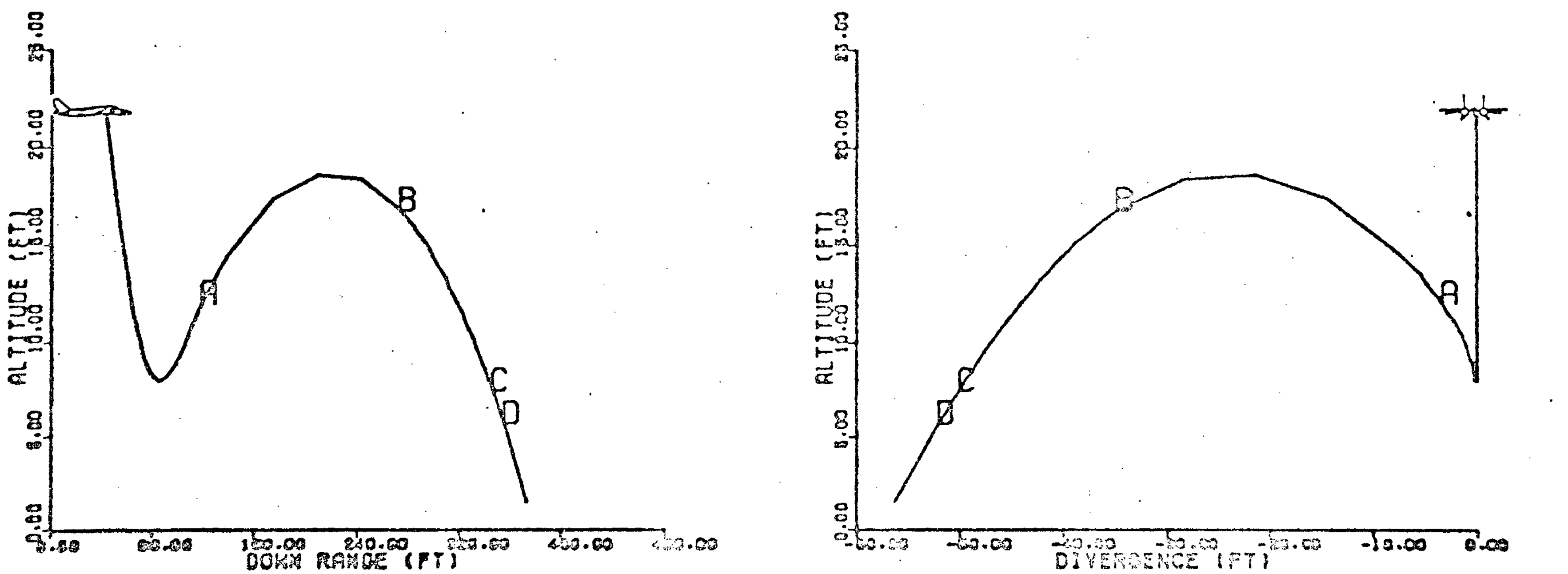


Figure A-22

PERFORMANCE TEST 3 - INITIAL CONDITIONS: 50 KNOTS 98 PERCENTILE
ALTITUDE: 20 FT SINK RATE: 20 FT/SEC PITCH: 0 DEG ROLL: 30 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

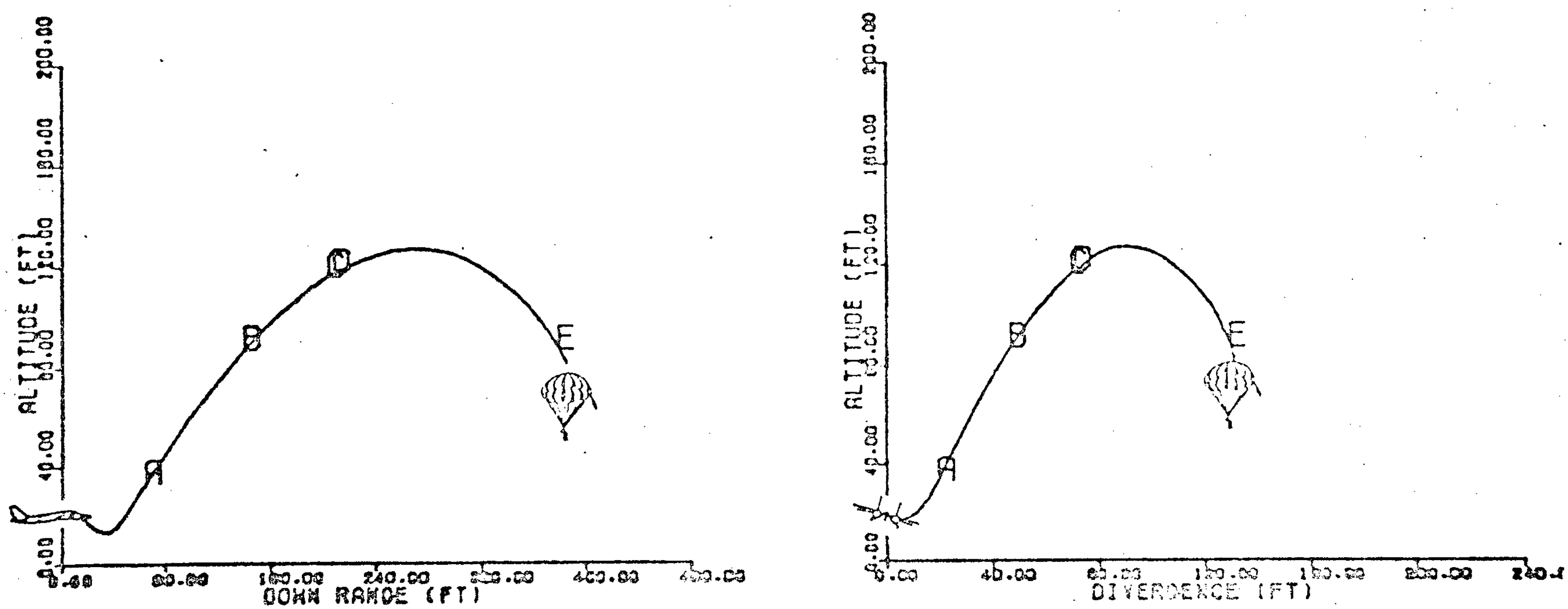


Figure A-23

PERFORMANCE TEST 4 - INITIAL CONDITIONS: 50 KNOTS 98 PERCENTILE
ALTITUDE: 25 FT SINK RATE: 33 FT/SEC PITCH: 0 DEG ROLL: 30 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

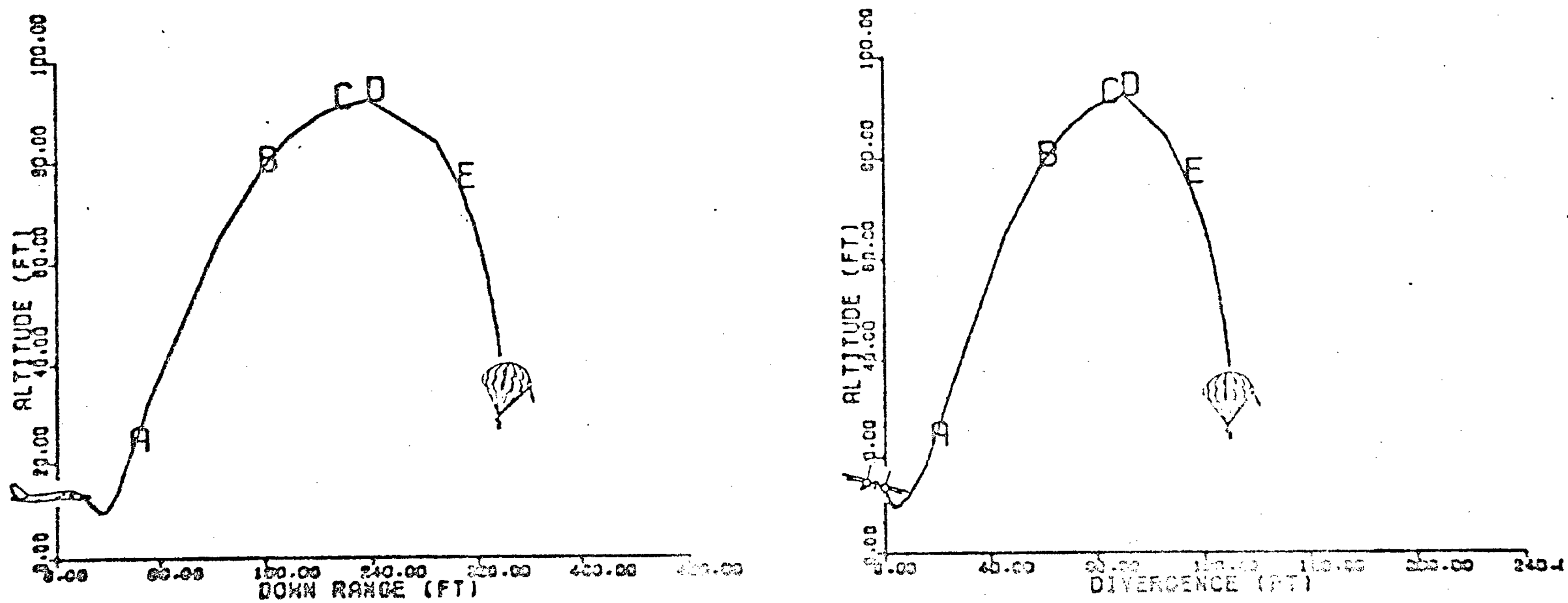
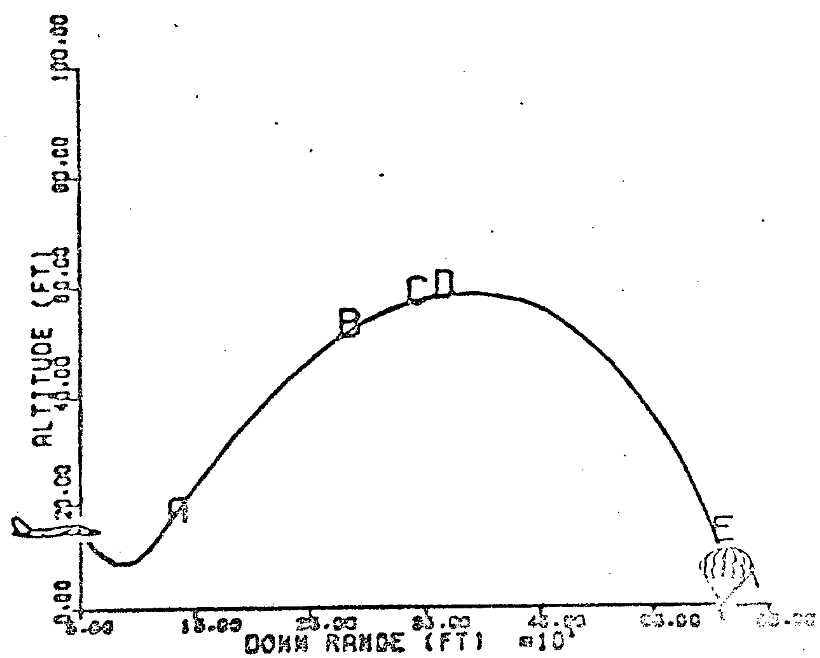


Figure A-24

PERFORMANCE TEST 5 - INITIAL CONDITIONS: 100 KNOTS 98 PERCENTILE
ALTITUDE: 30 FT SINK RATE: 50 FT/SEC PITCH: 0 DEG ROLL: 30 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION



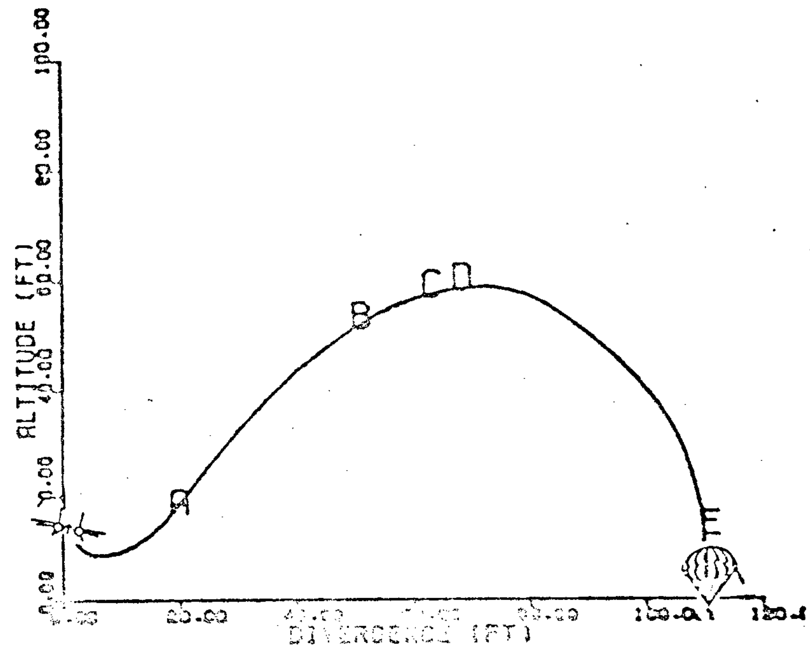
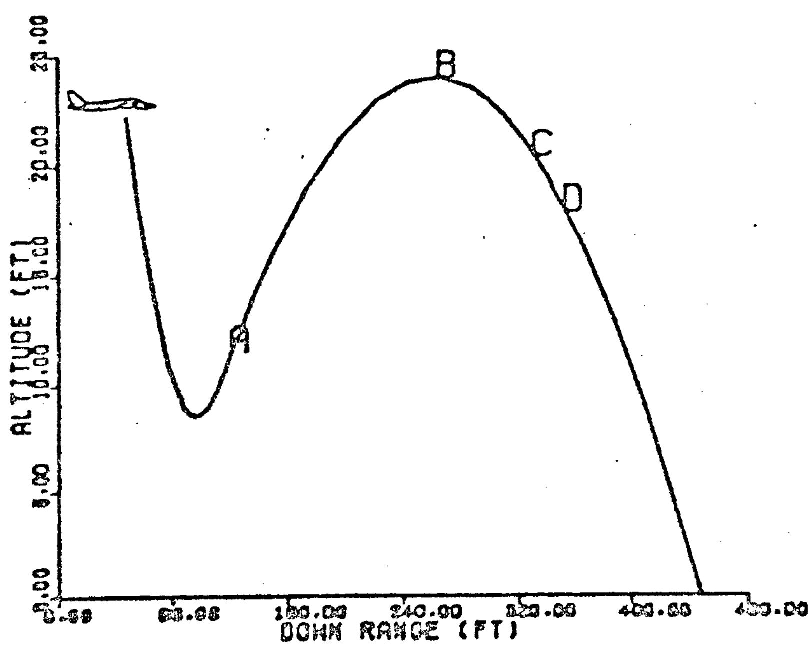


Figure A-25

PERFORMANCE TEST 6 - INITIAL CONDITIONS: 100 KNOTS 98 PERCENTILE
ALTITUDE: 45 FT SINK RATE: 75 FT/SEC PITCH: 0 DEG ROLL: 30 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION



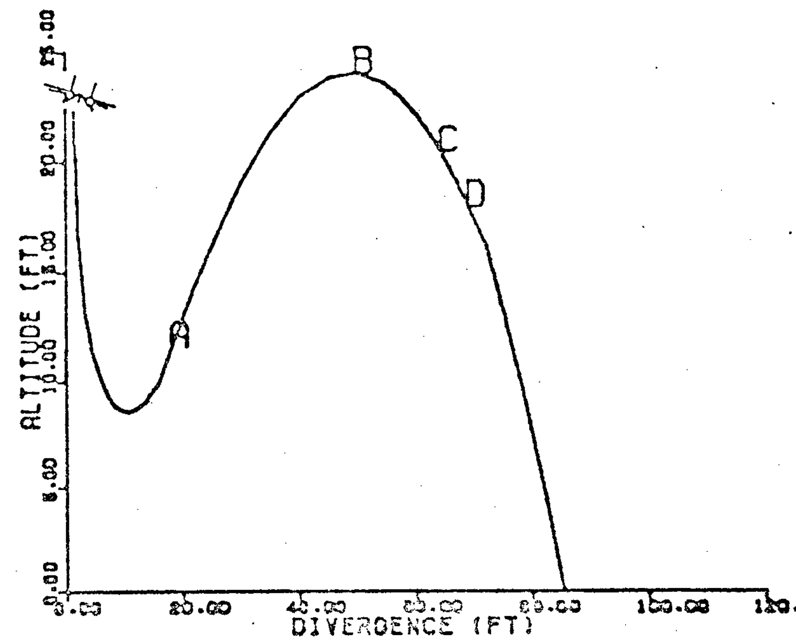


Figure A-26

PERFORMANCE TEST 7 - INITIAL CONDITIONS: 100 KNOTS 98 PERCENTILE
ALTITUDE: 20 FT SINK RATE: 33 FT/SEC PITCH: 0 DEG ROLL: 45 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

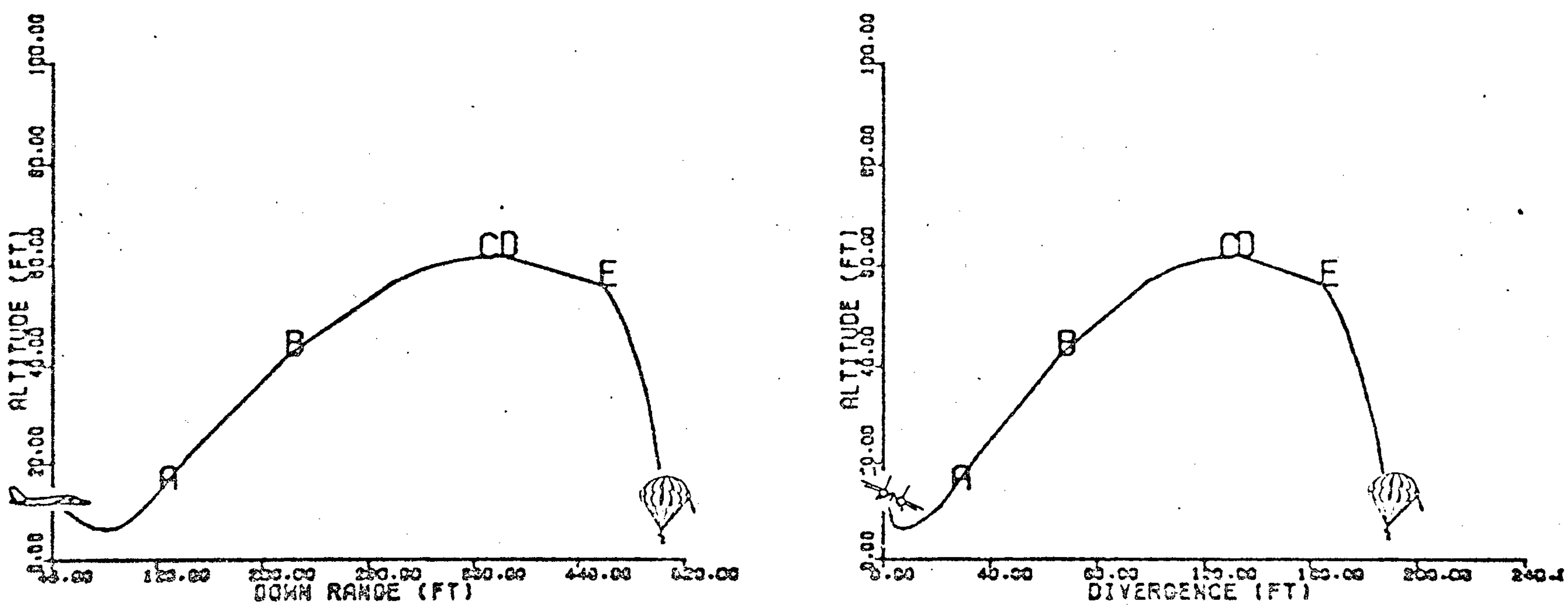


Figure A-27

PERFORMANCE TEST 8 - INITIAL CONDITIONS: 100 KNOTS 98 PERCENTILE
ALTITUDE: 124 FT SINK RATE: 83 FT/SEC PITCH: 0 DEG ROLL 45 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

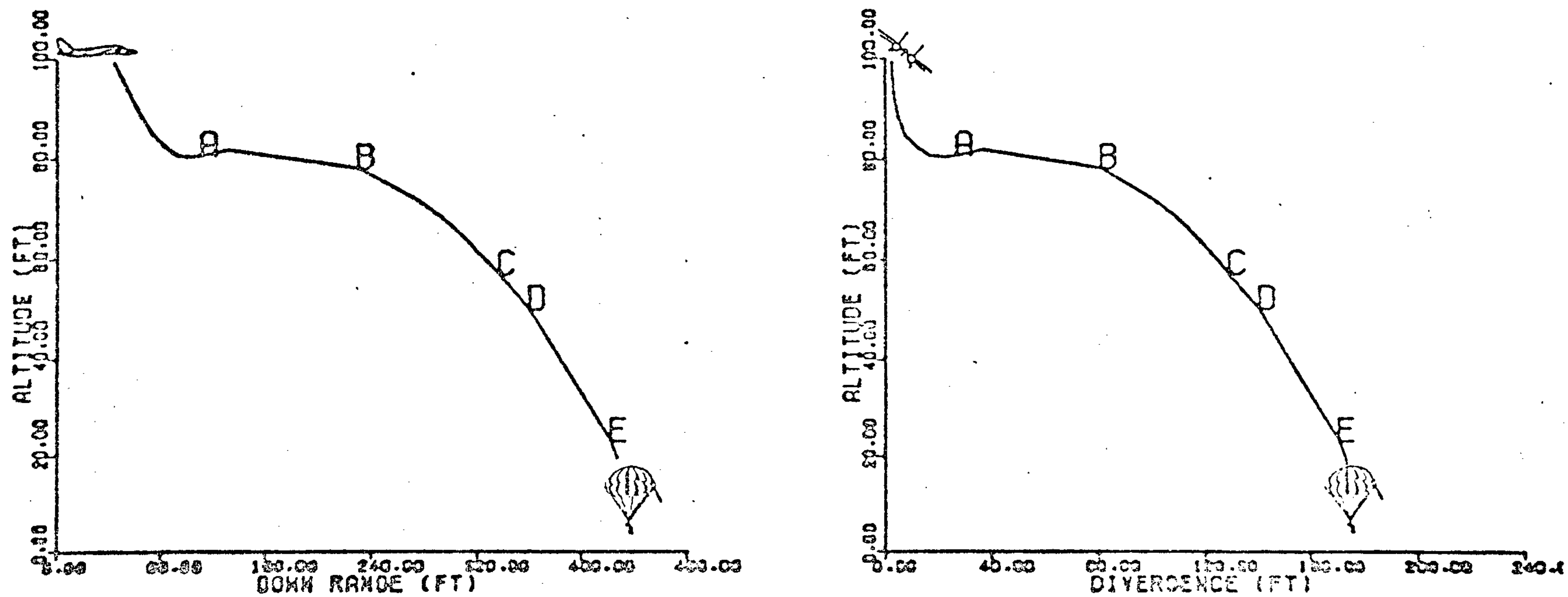


Figure A-28

PERFORMANCE TEST 9 - INITIAL CONDITIONS: 100 KNOTS 98 PERCENTILE
ALTITUDE: 201 FT SINK RATE: 33 FT/SEC PITCH: 0 DEG ROLL: 90 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

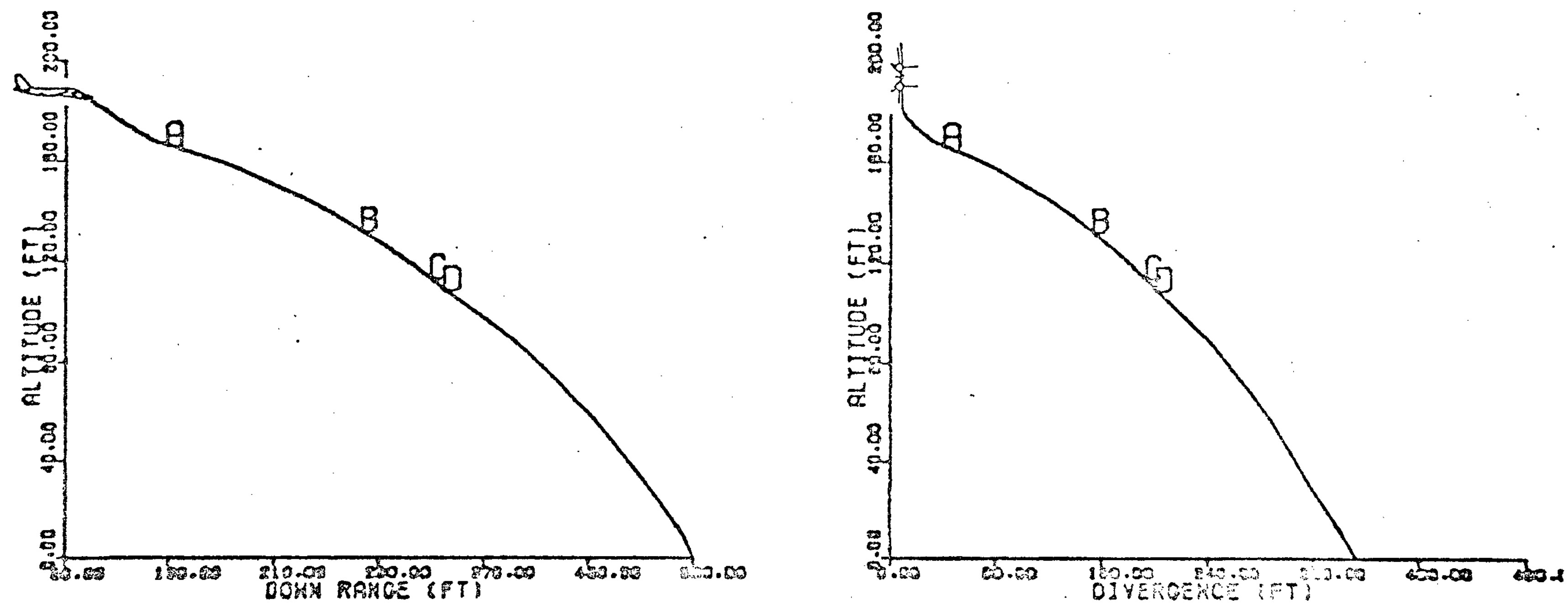


Figure A-29

PERFORMANCE TEST 10 - INITIAL CONDITIONS: 100 KNOTS 98 PERCENTILE
ALTITUDE: 320 FT SINK RATE: 83 FT/SEC PITCH: 0 DEG ROLL: 90 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATCCC SEPARATION
E-FULL INFLATION

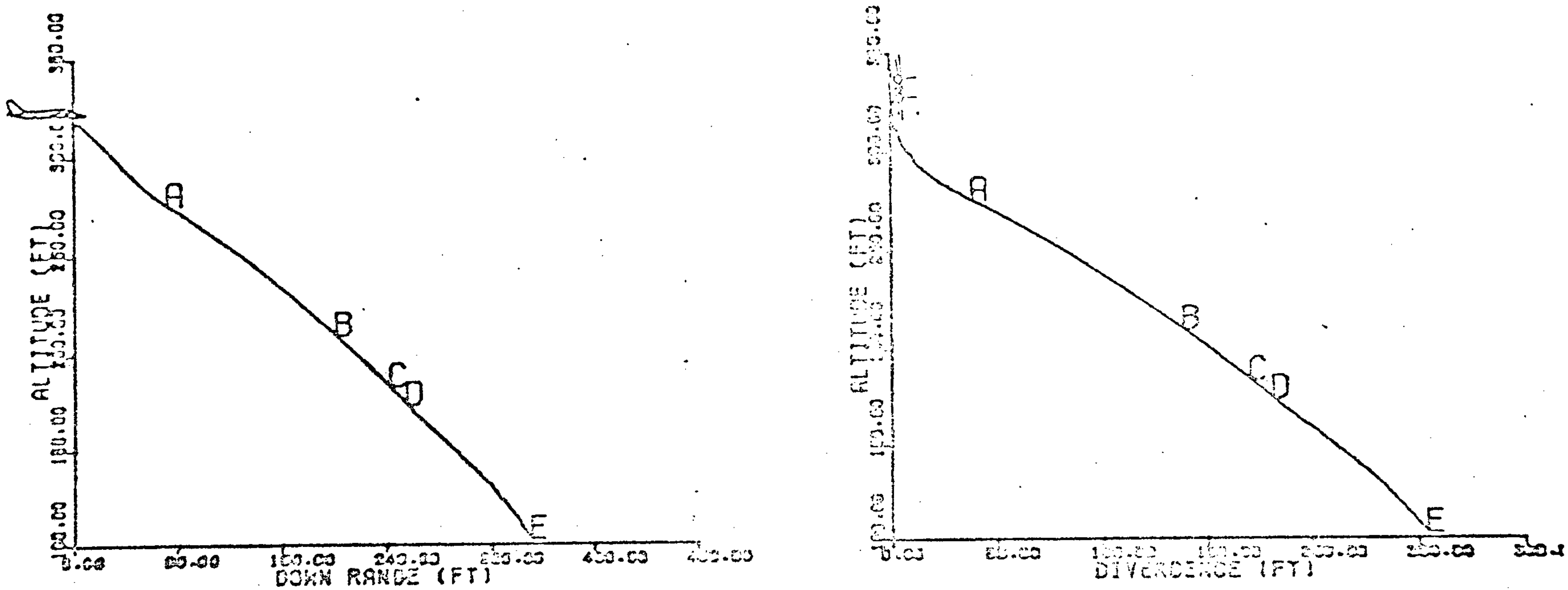
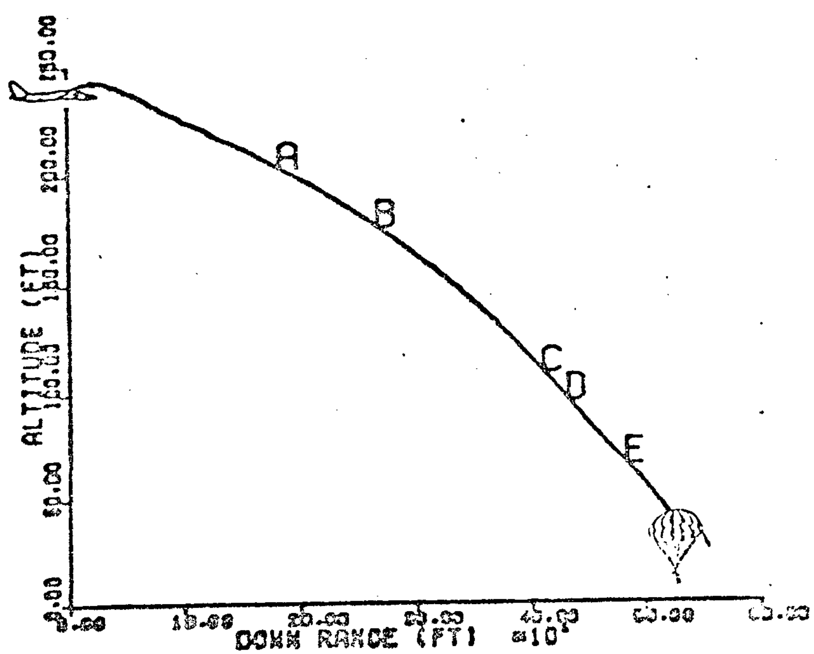


Figure A-30

PERFORMANCE TEST 11 - INITIAL CONDITIONS: 130 KNOTS 98 PERCENTILE
ALTITUDE: 245 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 120 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION



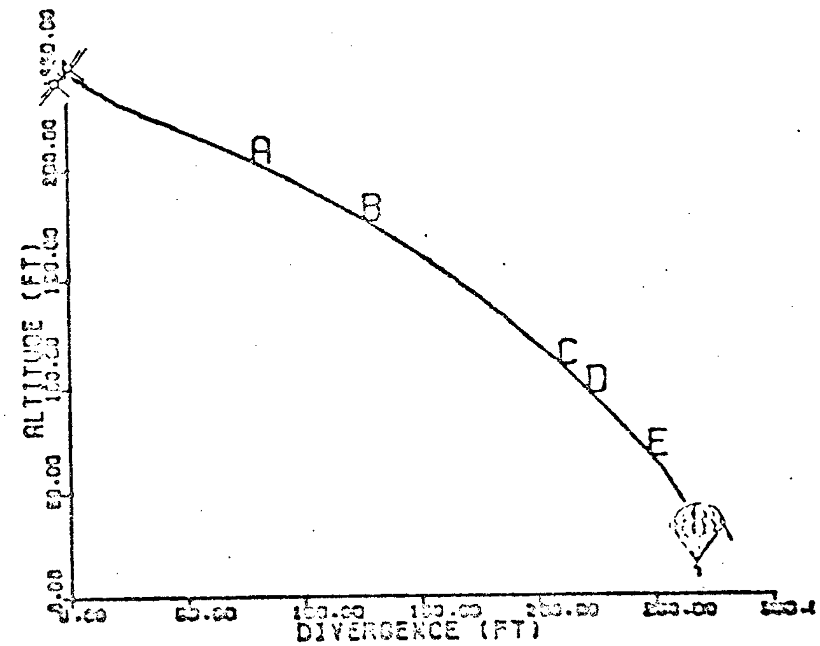


Figure A-31

PERFORMANCE TEST 12 - INITIAL CONDITIONS: 130 KNOTS 98 PERCENTILE
ALTITUDE: 350 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 150 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

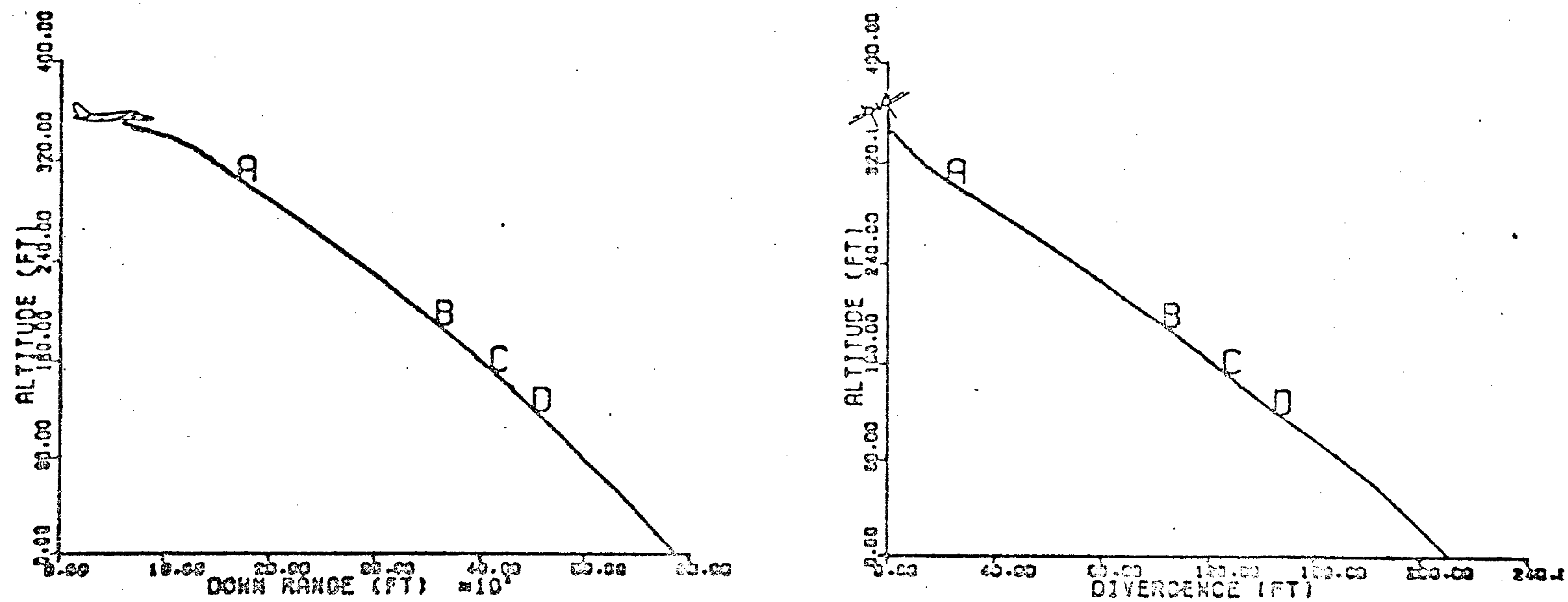
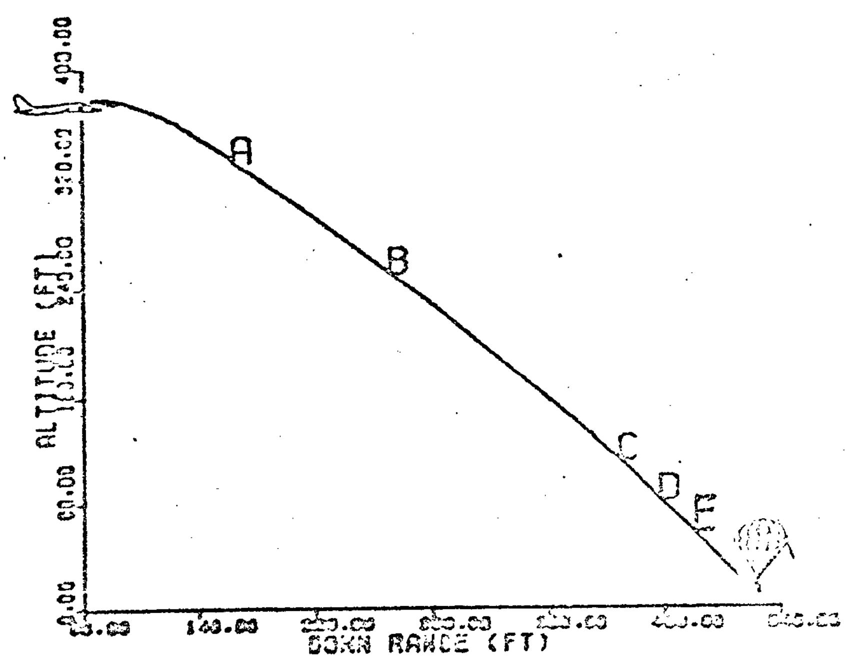


Figure A-32

PERFORMANCE TEST 13 - INITIAL CONDITIONS: 130 KNOTS 98 PERCENTILE
ALTITUDE: 384 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 180 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION



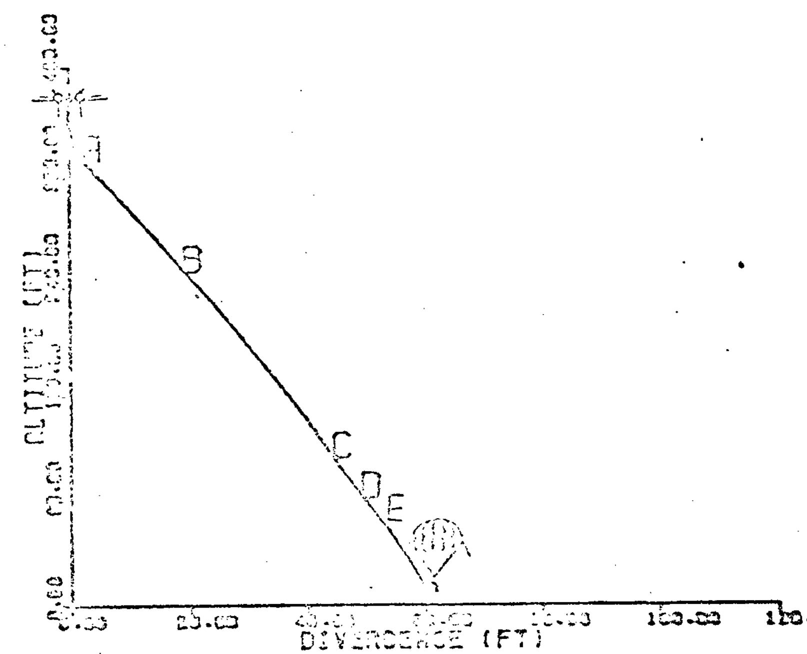


Figure A-33

PERFORMANCE TEST 14 - INITIAL CONDITIONS: 130 KNOTS 98 PERCENTILE
ALTITUDE: 15 FT SINK RATE: 20 FT/SEC PITCH: -5 DEG ROLL: 0 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

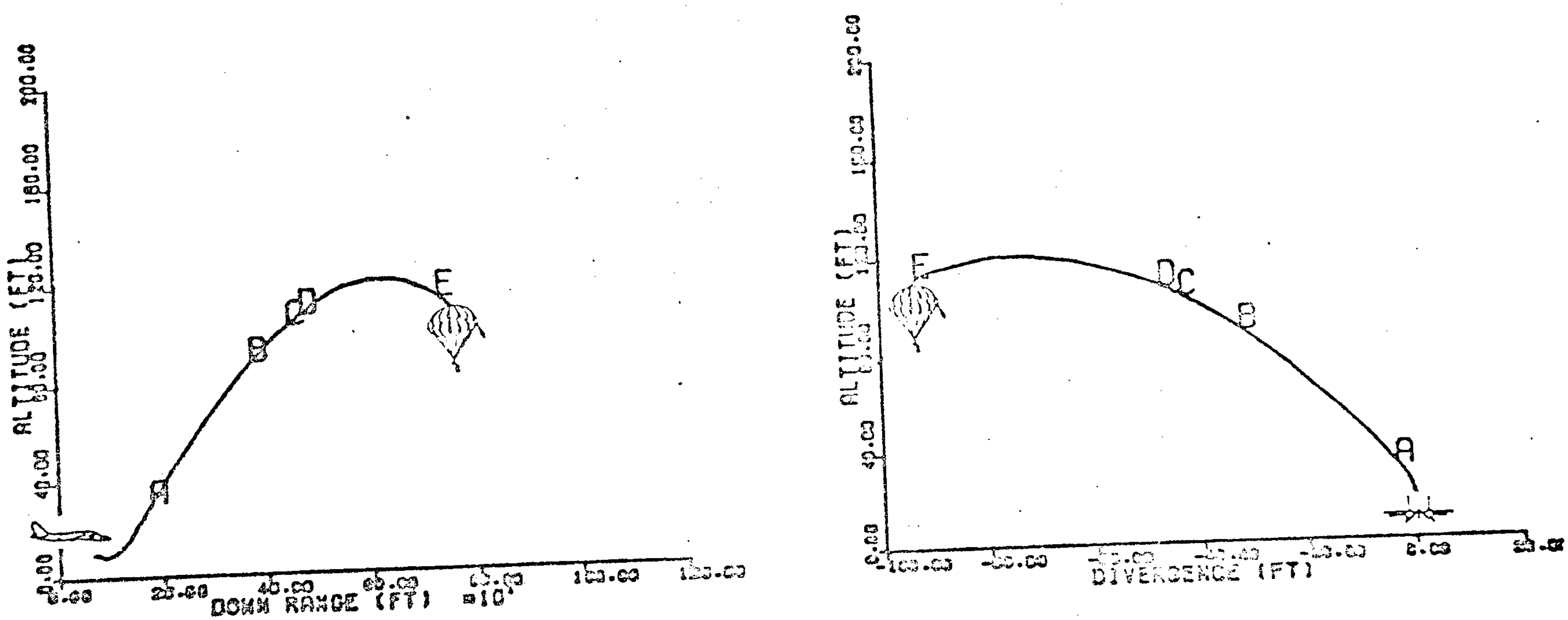


Figure A-34

PERFORMANCE TEST 15 - INITIAL CONDITIONS: 130 KNOTS 98 PERCENTILE
ALTITUDE: 20 FT SINK RATE: 33 FT/SEC PITCH: -10 DEG ROLL: 0 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

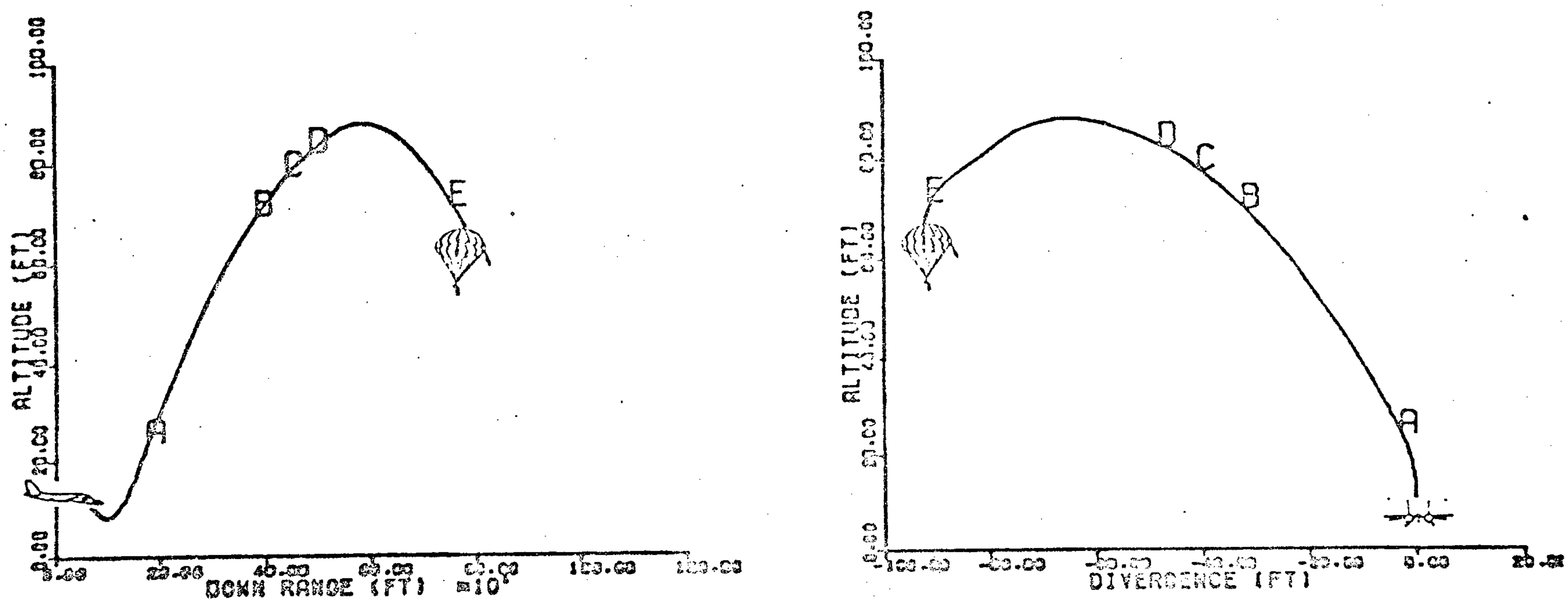


Figure A-35

PERFORMANCE TEST 16 - INITIAL CONDITIONS: 130 KNOTS 98 PERCENTILE
ALTITUDE: 30 FT SINK RATE: 50 FT/SEC PITCH: -15 DEG ROLL: 0 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

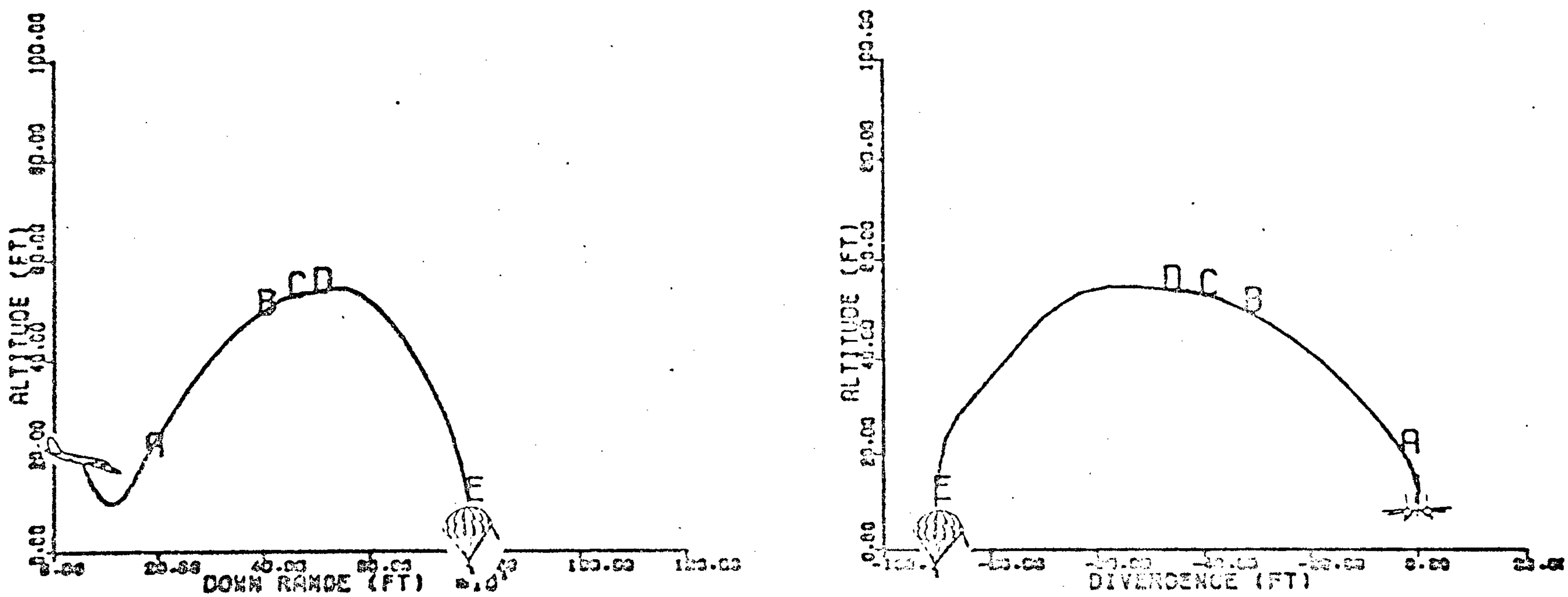
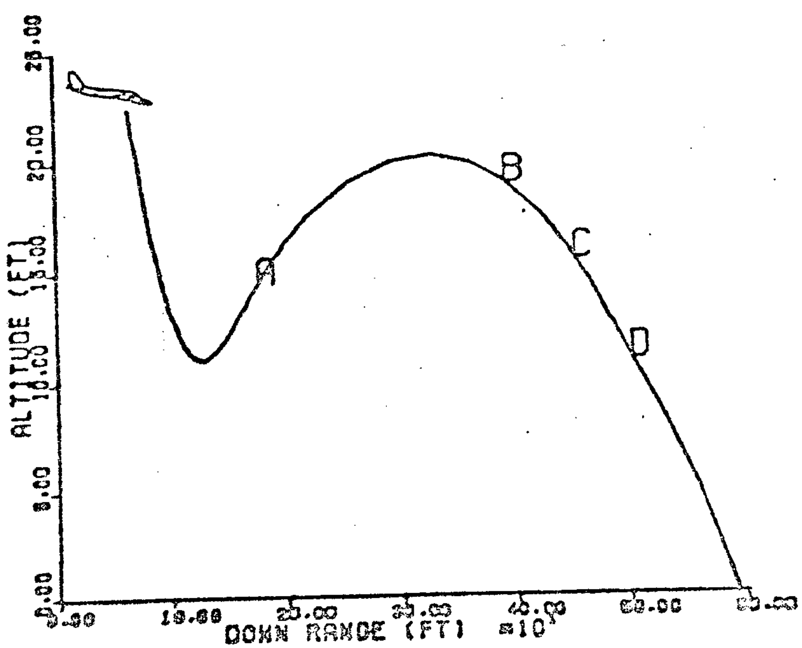


Figure A-36

PERFORMANCE TEST 17 - INITIAL CONDITIONS: 130 KNOTS 98 PERCENTILE
ALTITUDE: 45 FT SINK RATE: 75 FT/SEC PITCH: -20 DEG ROLL: 0 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION



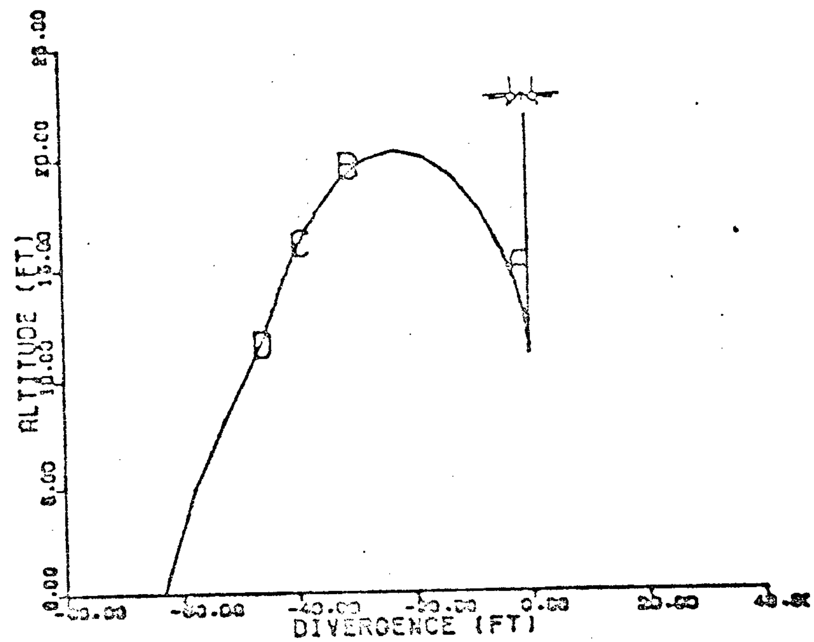


Figure A-37

PERFORMANCE TEST 18 - INITIAL CONDITIONS: 350 KNOTS 98 PERCENTILE
ALTITUDE: 22 FT SINK RATE: 40 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

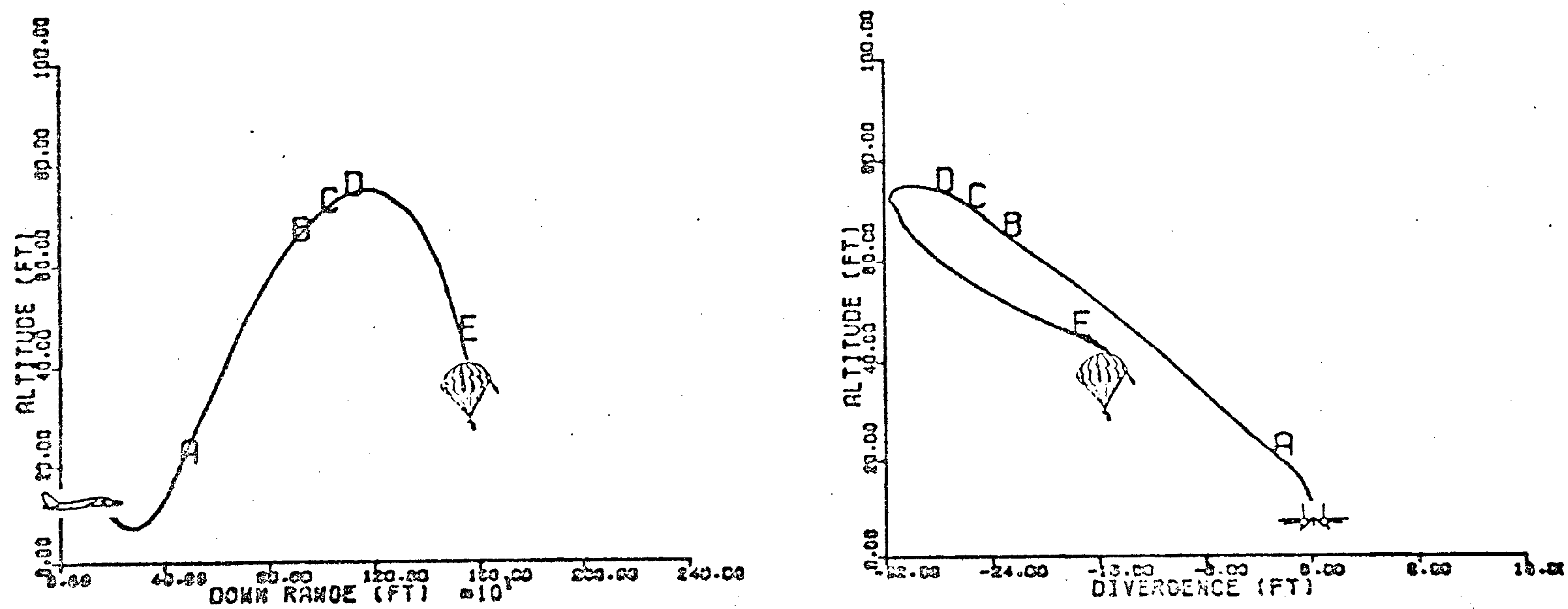


Figure A-38

PERFORMANCE TEST 19 - INITIAL CONDITIONS: 600 KNOTS 98 PERCENTILE
ALTITUDE: 22 FT SINK RATE: 40 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

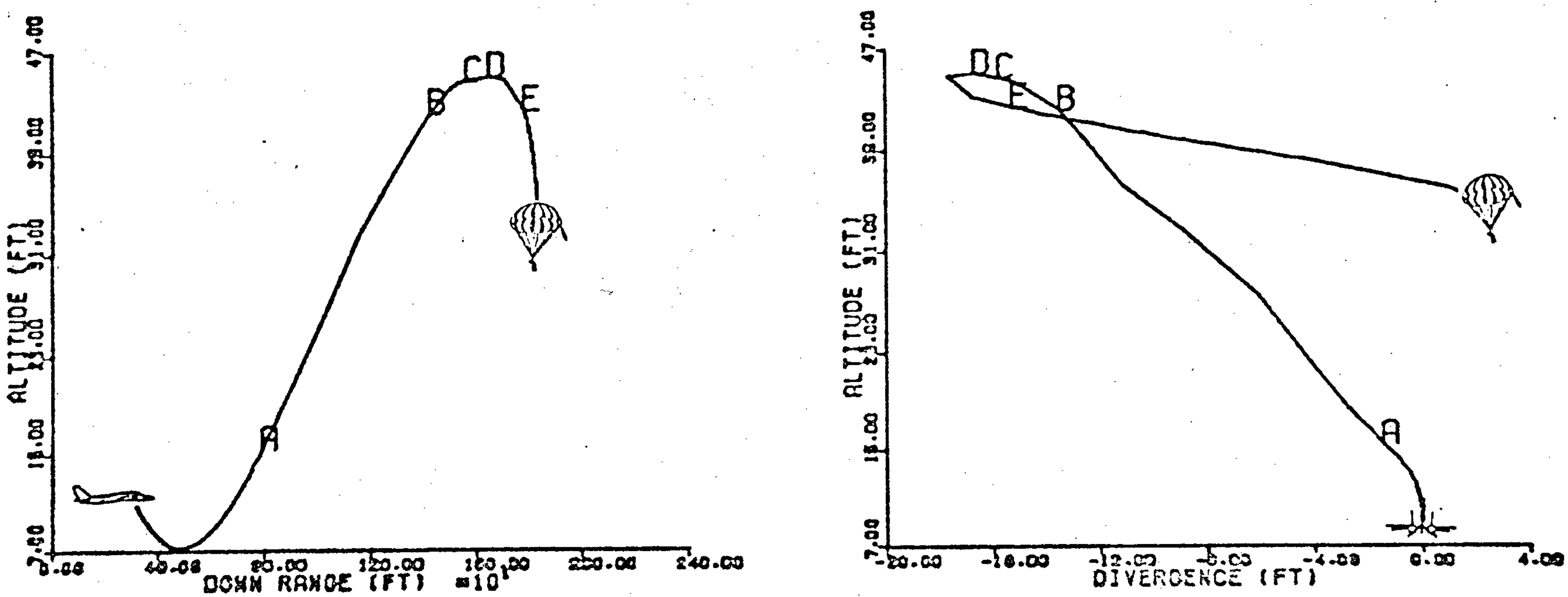
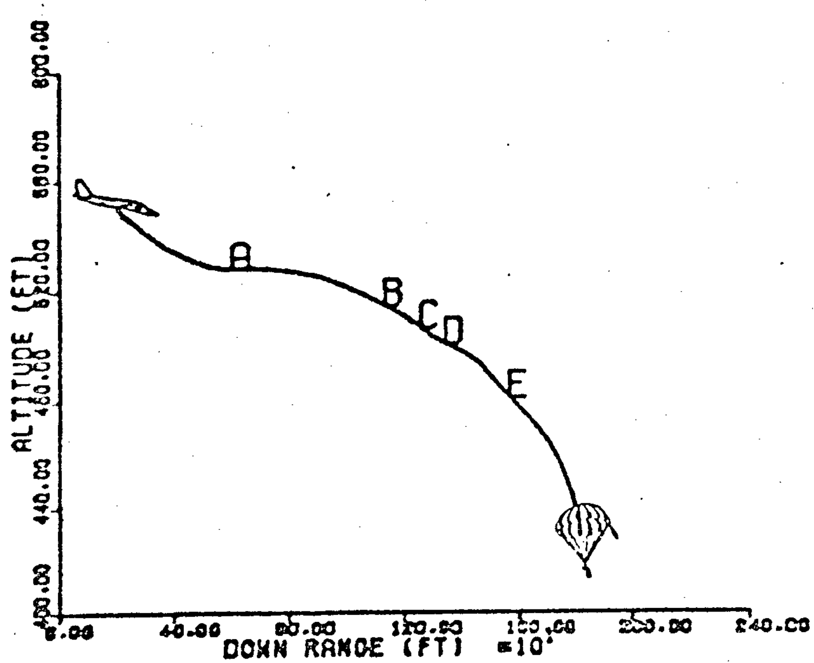


Figure A-39

PERFORMANCE TEST 20 - INITIAL CONDITIONS: 450 KNOTS 98 PERCENTILE
ALTITUDE: 570 FT SINK RATE: 75 FT/SEC PITCH: -30 DEG ROLL: 0 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION



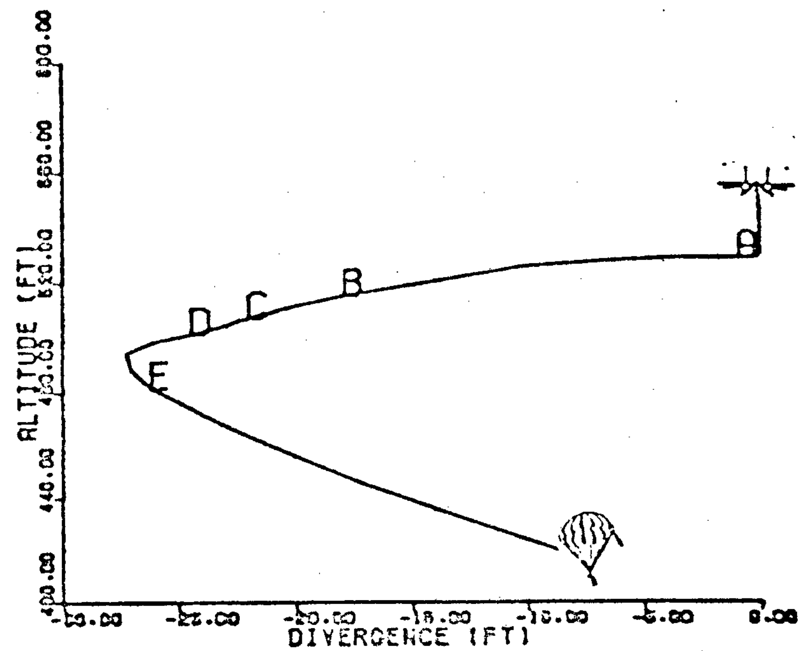


Figure A-40

PERFORMANCE TEST 21 - INITIAL CONDITIONS: 0 KNOTS 98 PERCENTILE
ALTITUDE: 0 FT SINK RATE: 0 FT/SEC PITCH: -20 DEG ROLL: 0 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

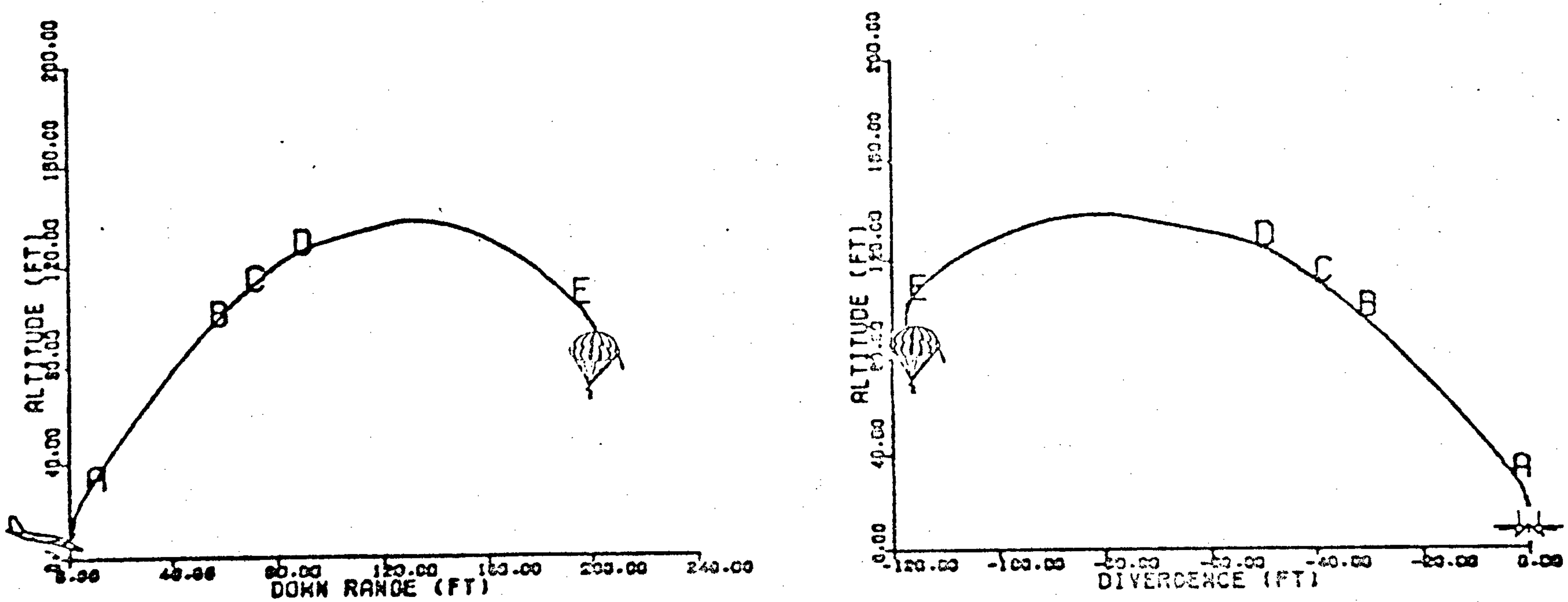
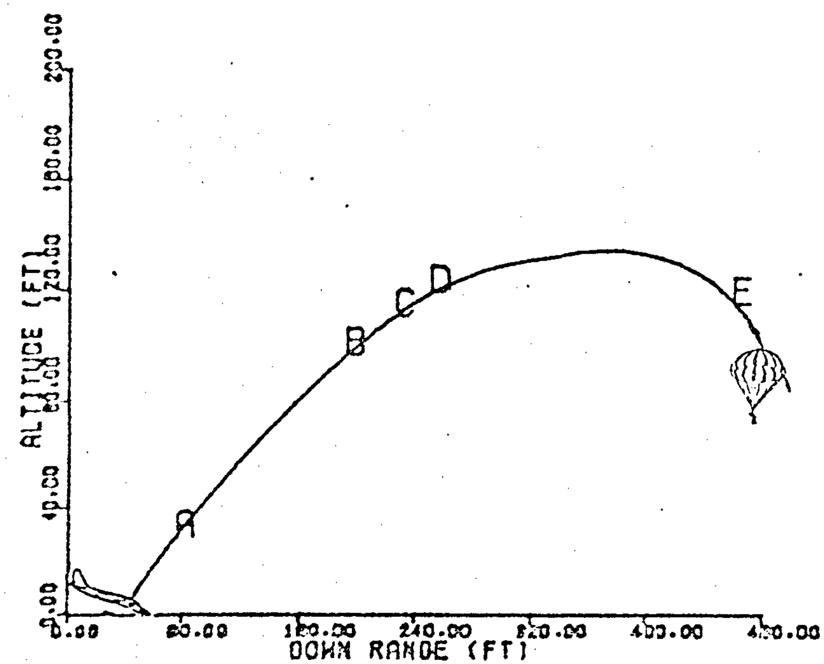


Figure A-41

PERFORMANCE TEST 22 - INITIAL CONDITIONS: 50 KNOTS 98 PERCENTILE
ALTITUDE: 0 FT SINK RATE: 0 FT/SEC PITCH: -20 DEG ROLL: 0 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION



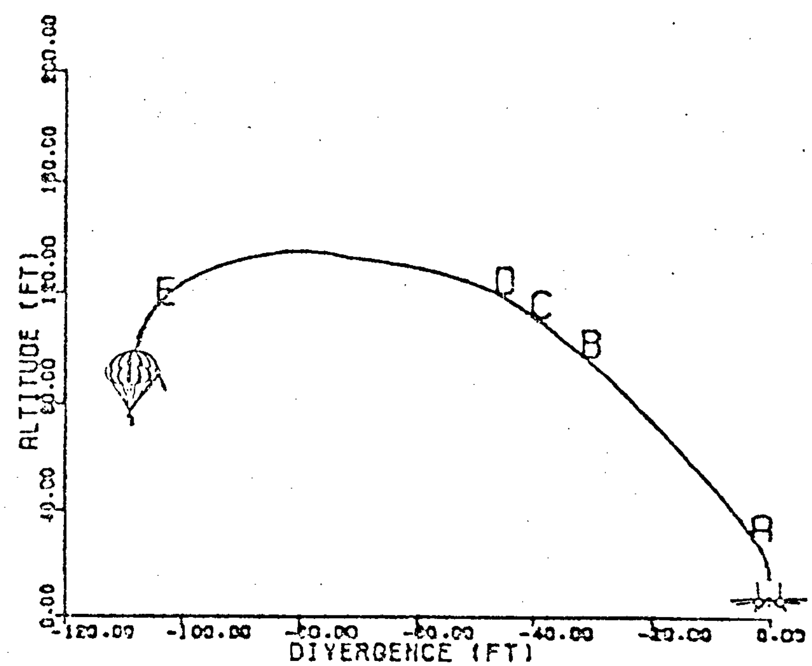


Figure A-42

APPENDIX B

CONTROLLED ANGULAR RATE STUDY PLOTS

ANGULAR RATE TEST - INITIAL CONDITIONS: 400 KNOTS 98 PERCENTILE
EJECTED WEIGHT:462 LBS FRONTAL AREA: 6 FT2 PITCH: 0 DEG ROLL: 0 DEG

○ NORMAL RATES
△ ZERO RATES

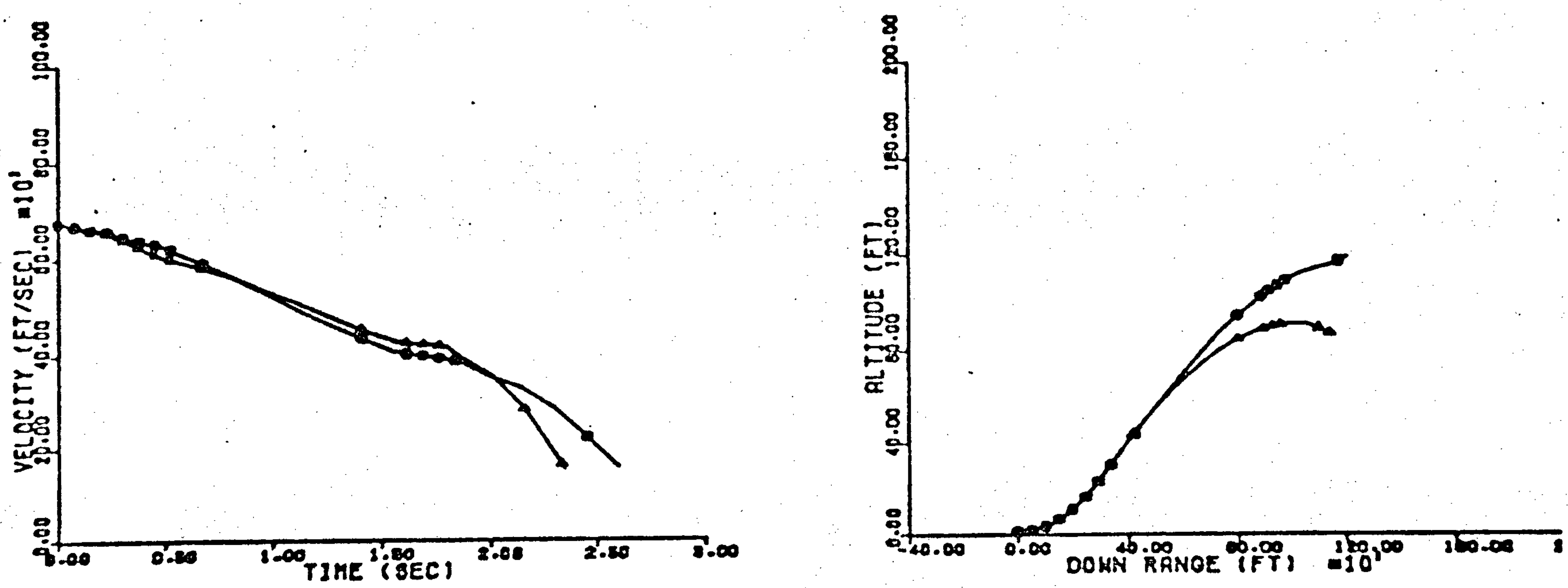


Figure B-1

ANGULAR RATE TEST - INITIAL CONDITIONS: 600 KNOTS 98 PERCENTILE
EJECTED WEIGHT:462 LBS FRONTAL AREA: 6 FT2 PITCH: 0 DEG ROLL: 0 DEG

⊙ NORMAL RATES
△ ZERO RATES

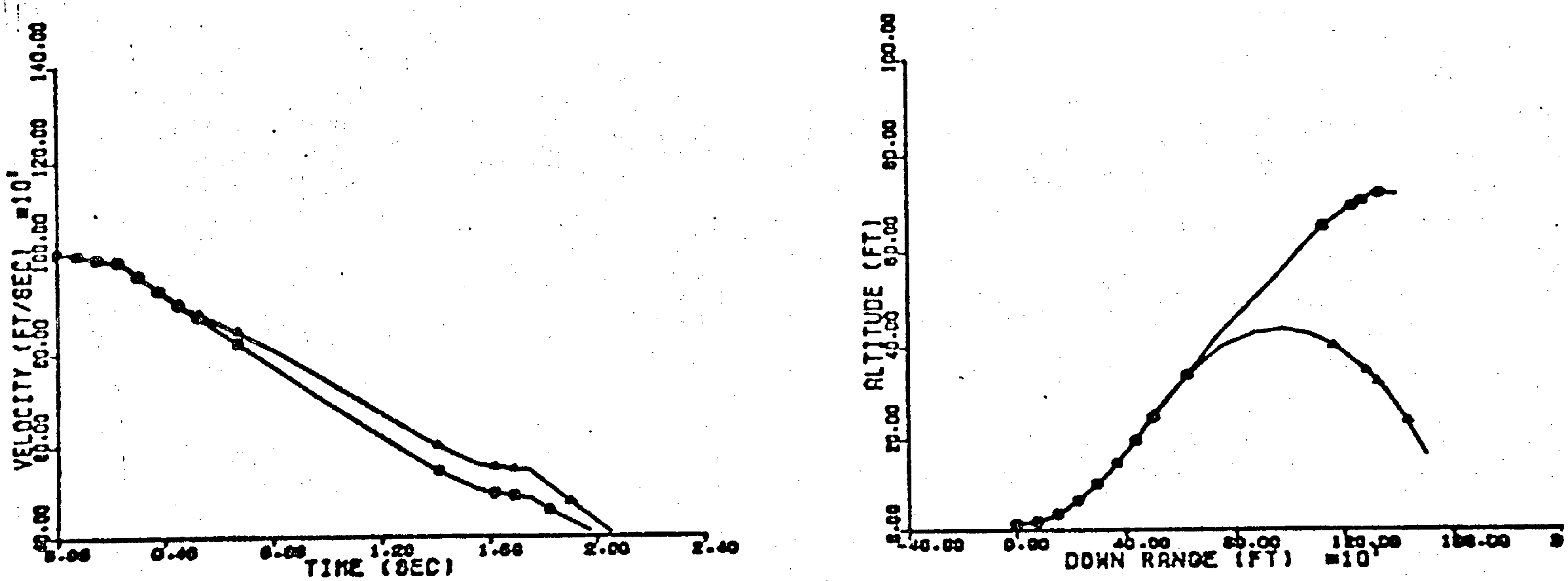


Figure B-2

APPENDIX C

F-14A DUAL MODE EJECTION SEAT STUDY PLOTS

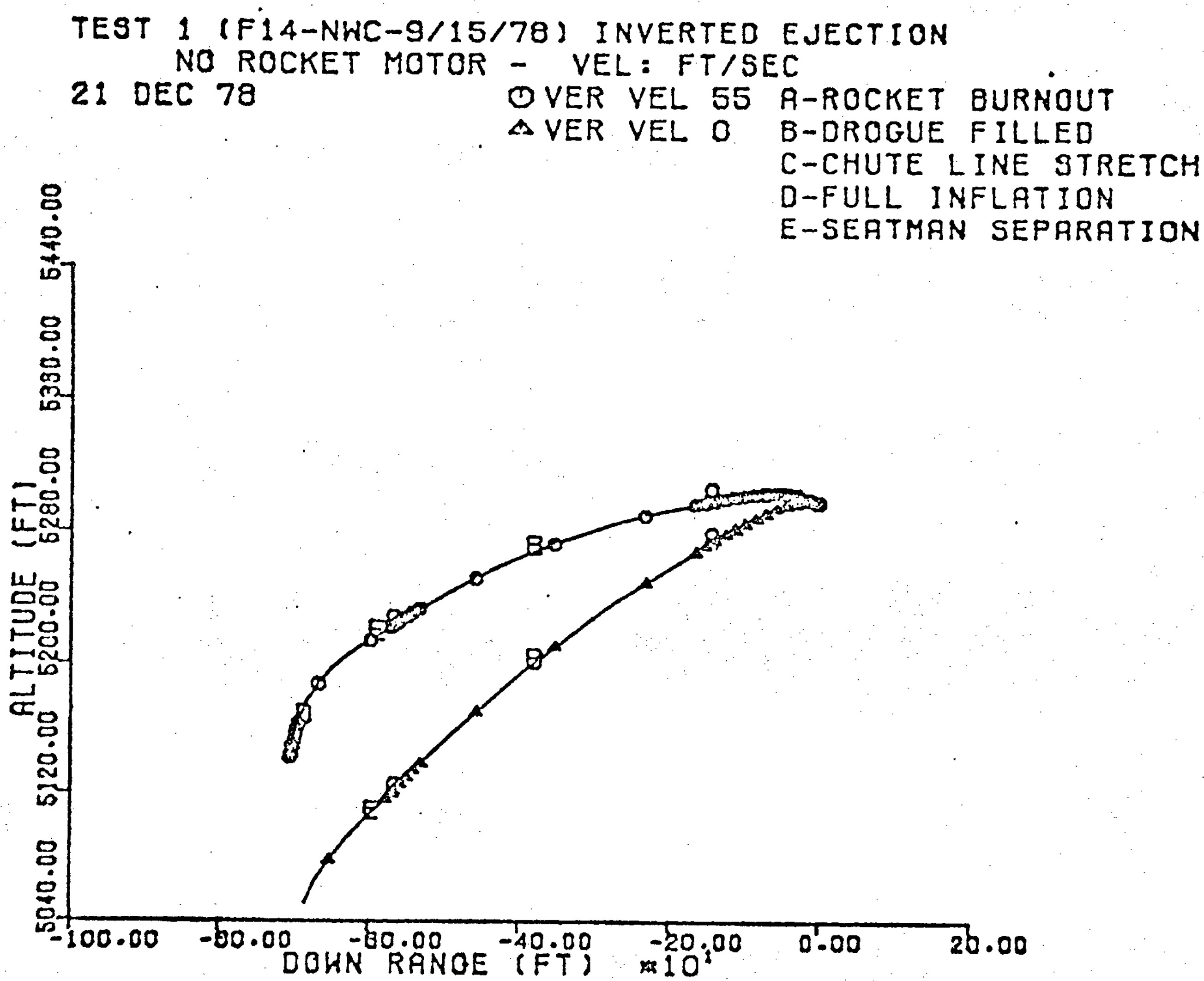
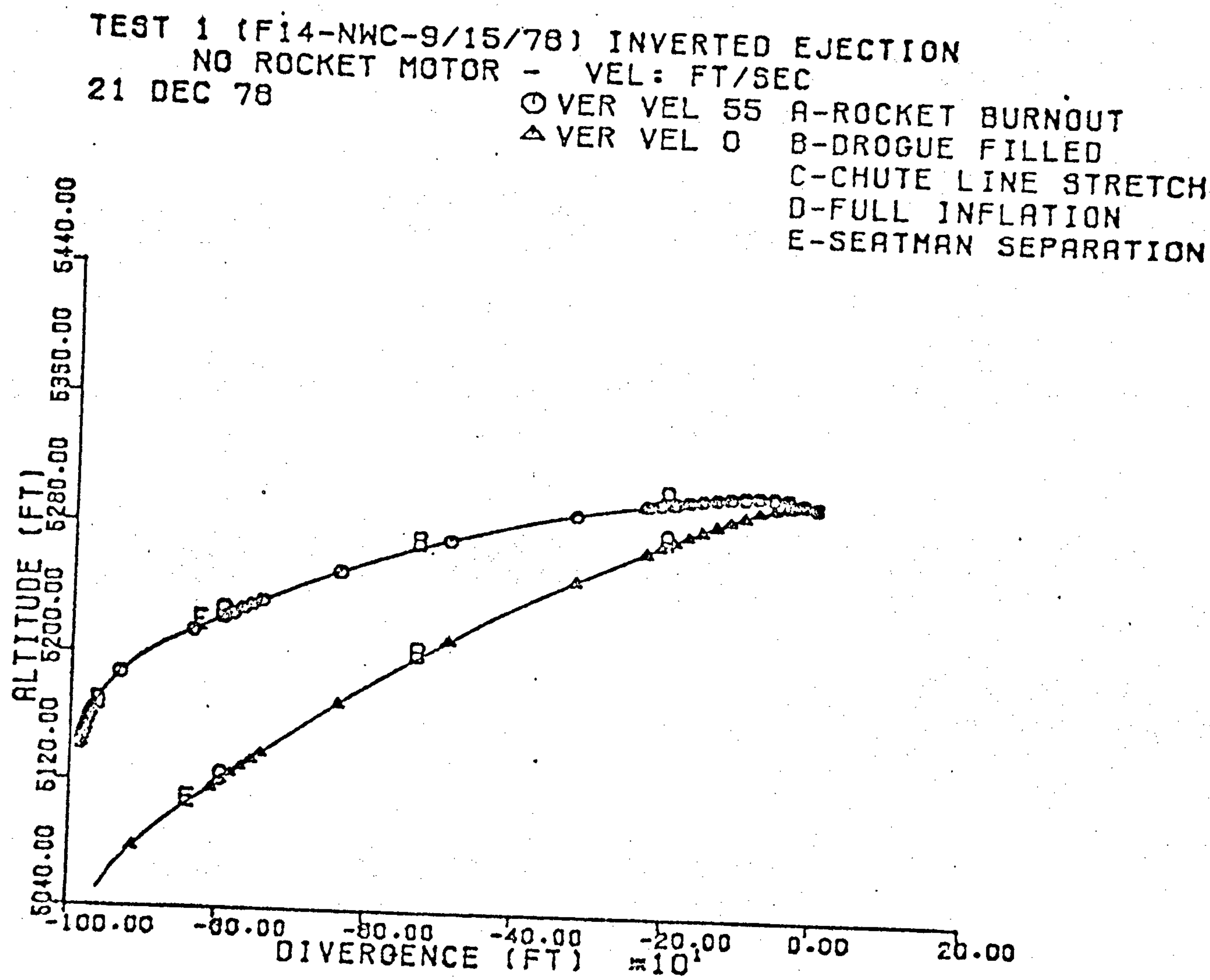

TEST 1 (F14-NWC-9/15/78) INVERTED EJECTION
NO ROCKET MOTOR - VEL: FT/SEC
21 DEC 78
VER VEL 55
VER VEL 0
A-ROCKET BURNOUT
B-DROGUE FILLED
C-CHUTE LINE STRETCH
D-FULL INFLATION
E-SEATMAN SEPARATION
ALTITUDE (FT)
5040.00
5120.00
5200.00
5280.00
5360.00
5440.00
DOWN RANGE (FT) $\times 10^{1}$
-100.00
-80.00
-60.00
-40.00
-20.00
0.00
20.00

Figure C-1



TEST 1 (F14-NWC-9/15/78) INVERTED EJECTION
NO ROCKET MOTOR - VEL: FT/SEC
21 DEC 78
VER VEL 55
VER VEL 0
A-ROCKET BURNOUT
B-DROGUE FILLED
C-CHUTE LINE STRETCH
D-FULL INFLATION
E-SEATMAN SEPARATION
ALTITUDE (FT)
5040.00
5120.00
5200.00
5280.00
5350.00
5440.00
DIVERGENCE (FT) *10¹
-100.00
-80.00
-60.00
-40.00
-20.00
0.00
20.00

Figure C-2

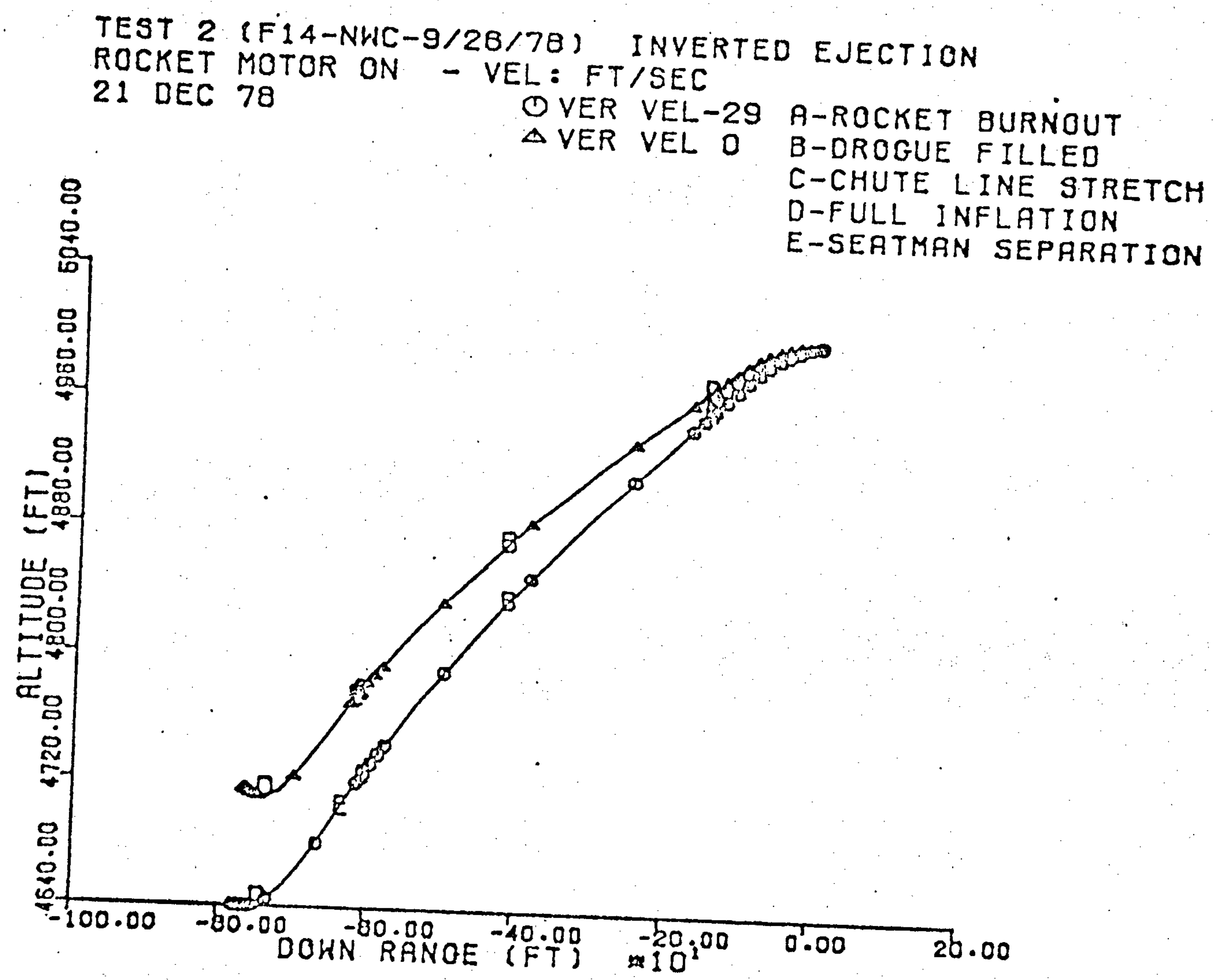

TEST 2 (F14-NWC-9/26/78) INVERTED EJECTION
ROCKET MOTOR ON - VEL: FT/SEC
21 DEC 78
VER VEL-29
VER VEL 0
A-ROCKET BURNOUT
B-DROGUE FILLED
C-CHUTE LINE STRETCH
D-FULL INFLATION
E-SEATMAN SEPARATION
ALTITUDE (FT)
4640.00
4720.00
4800.00
4880.00
4960.00
5040.00
DOWN RANGE (FT) *10¹
-100.00
-80.00
-40.00
-20.00
0.00
20.00

Figure C-3

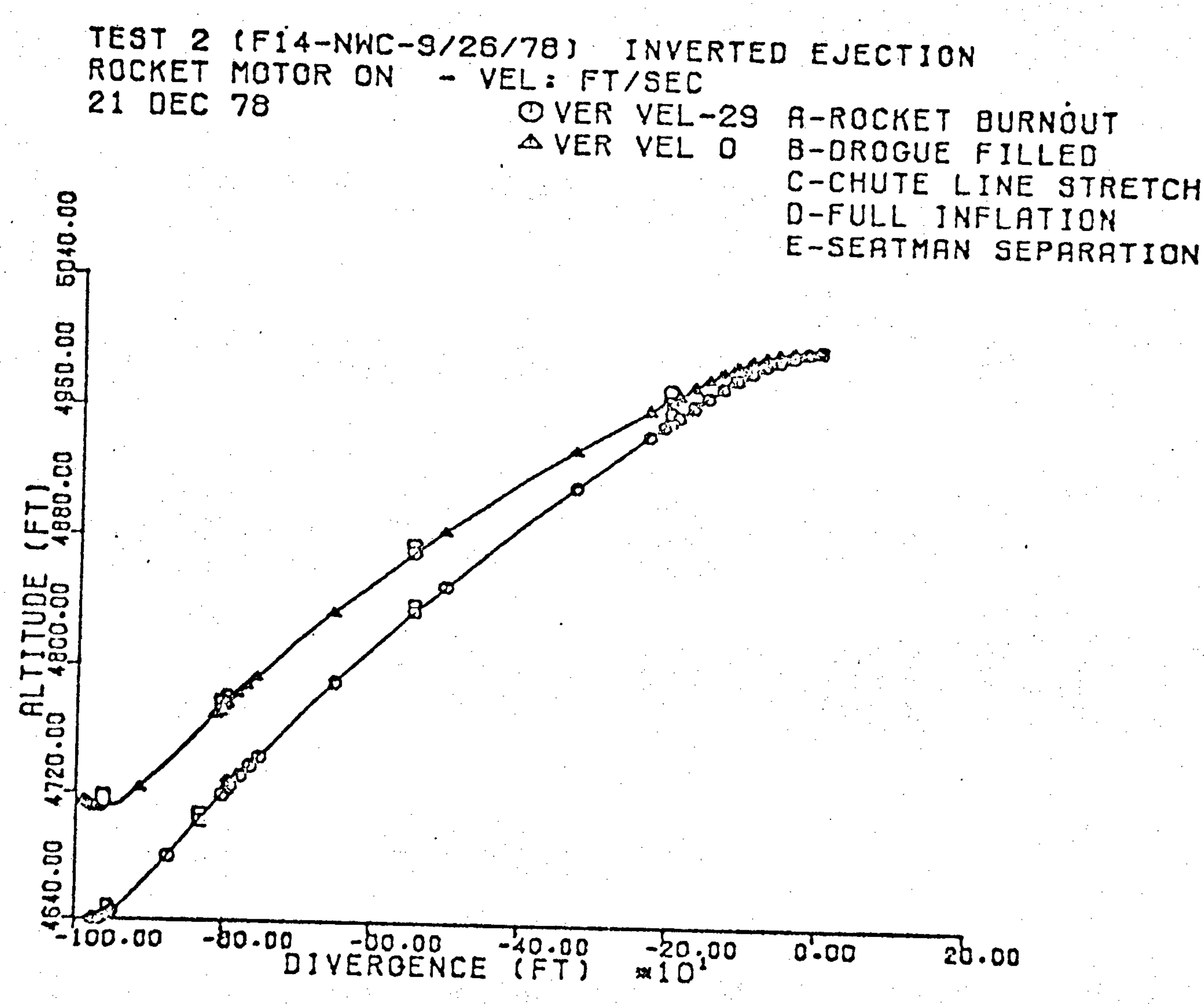

TEST 2 (F14-NWC-9/26/78) INVERTED EJECTION
ROCKET MOTOR ON - VEL: FT/SEC
21 DEC 78
VER VEL-29
VER VEL 0
A-ROCKET BURNOUT
B-DROGUE FILLED
C-CHUTE LINE STRETCH
D-FULL INFLATION
E-SEATMAN SEPARATION
ALTITUDE (FT)
4640.00
4720.00
4800.00
4880.00
4960.00
5040.00
-100.00
-80.00
-60.00
-40.00
-20.00
0.00
20.00
DIVERGENCE (FT) *10¹

Figure C-4

F14 DUAL MODE EJECTION SYSTEM
FRONT SEAT 98 PERCENTILE SPEED=323.6 KNOTS
ALT=5298.5. SINK RATE=47.1. PITCH=0. ROLL=180

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

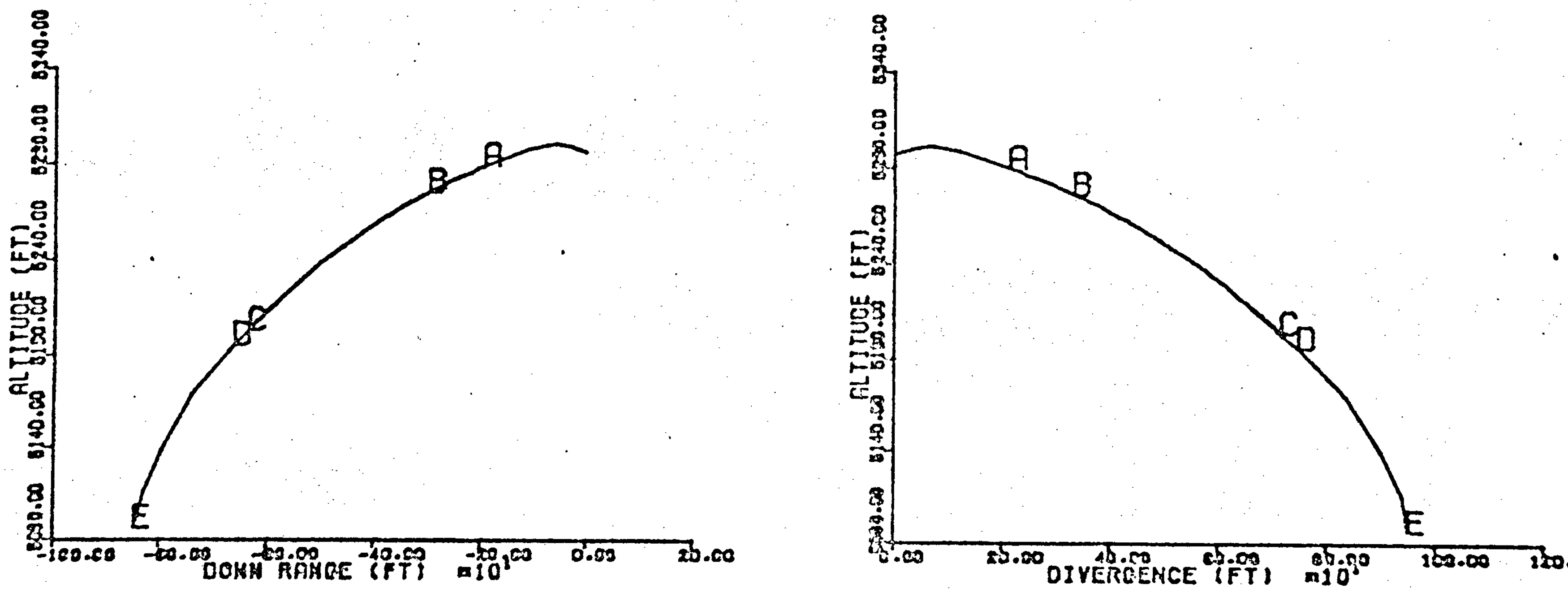


Figure C-5

F14 DUAL MODE EJECTION SYSTEM
FRONT SEAT 98 PERCENTILE SPEED=323.6 KNOTS
ALT=5298.5, SINK RATE=0, PITCH=15, ROLL=180

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

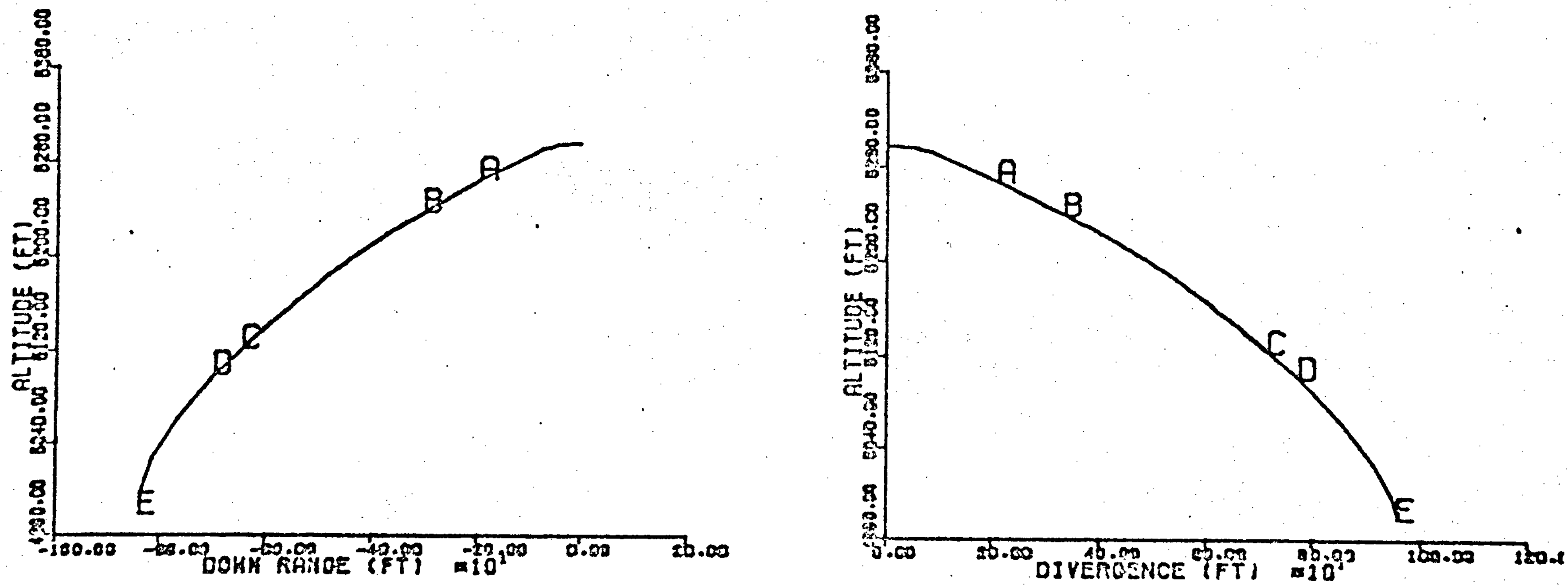
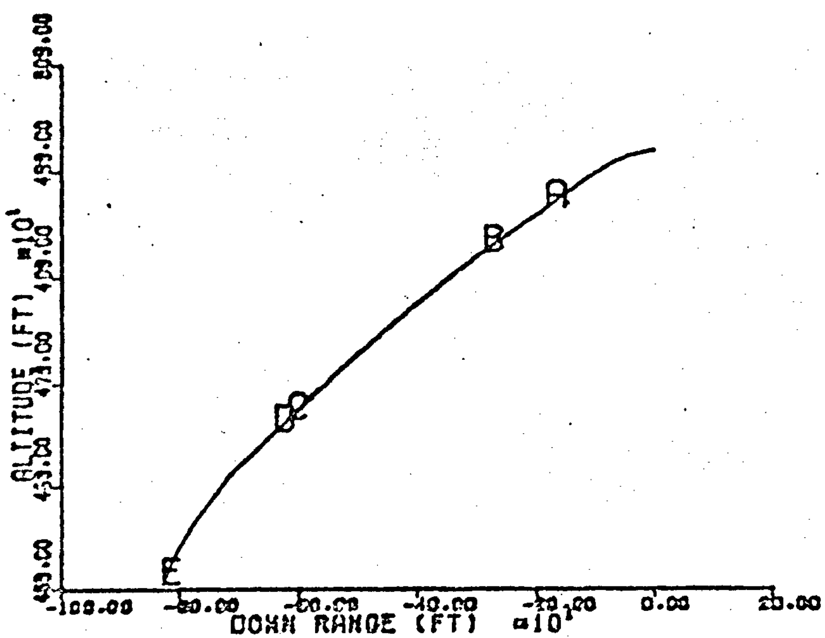


Figure C-6

F14 DUAL MODE EJECTION SYSTEM
FRONT SEAT 98 PERCENTILE SPEED=315.5 KNOTS
ALT=5012, SINK RATE=-25, PITCH=0, ROLL=180

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION



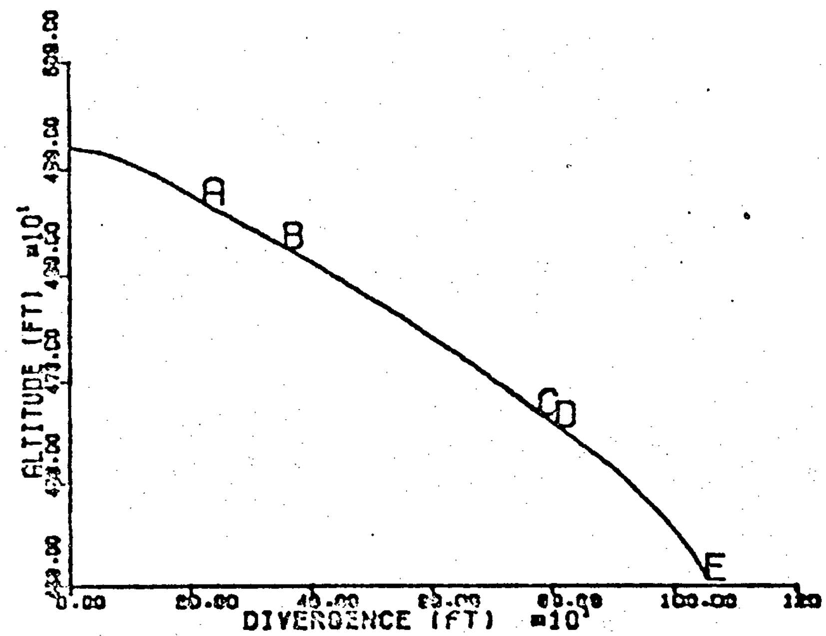


Figure C-7

F14 DUAL MODE EJECTION SYSTEM
FRONT SEAT 98 PERCENTILE SPEED=316.5 KNOTS
ALT=5012. SINK RATE=0. PITCH=15. ROLL=100

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

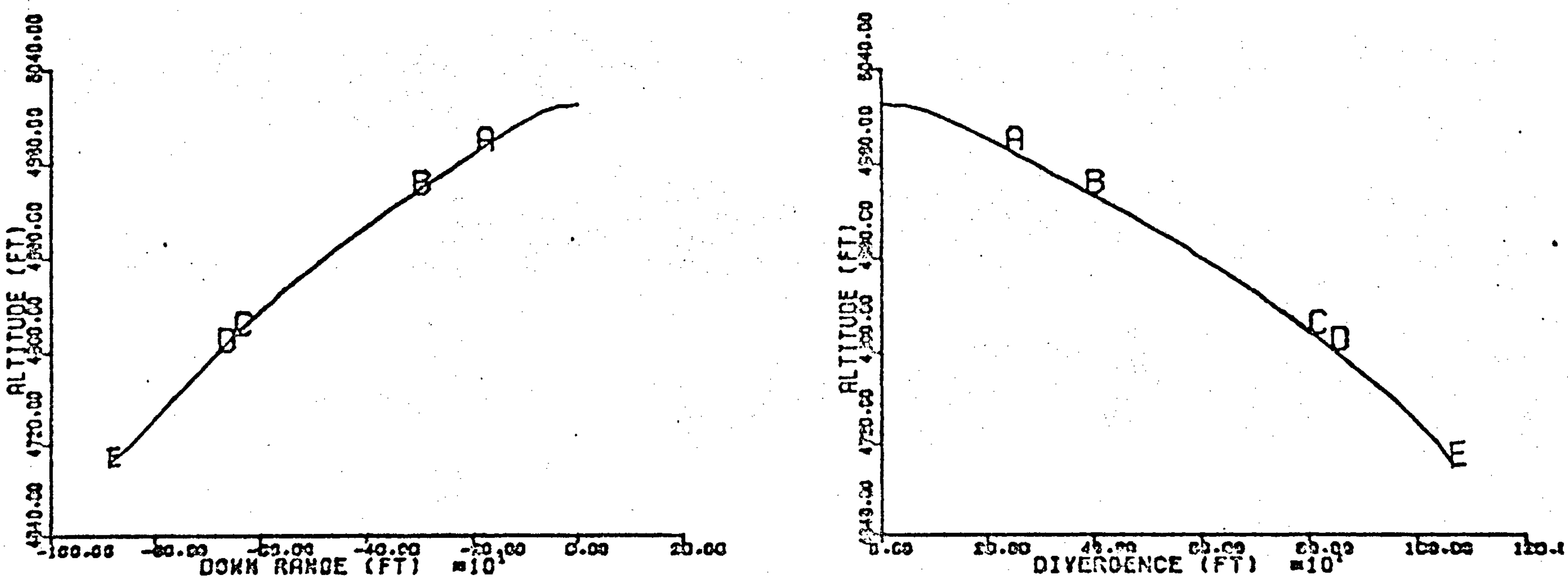


Figure C-8

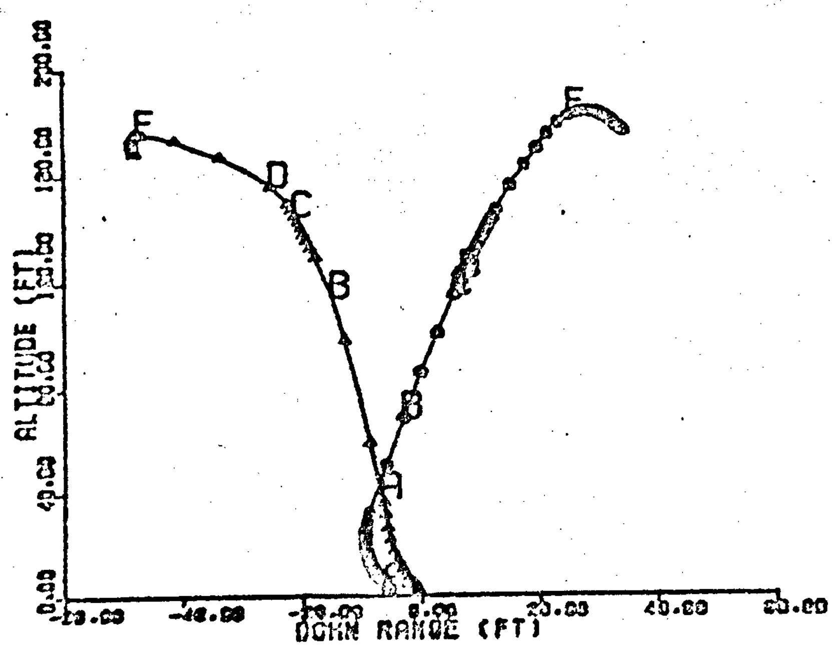
APPENDIX D

TF-18A ESCAPE SYSTEM PERFORMANCE STUDY PLOTS

TF-18 PERFORMANCE STUDY - TEST 1.1 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 0 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

O REAR SEAT
Δ FRONT SEAT

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION



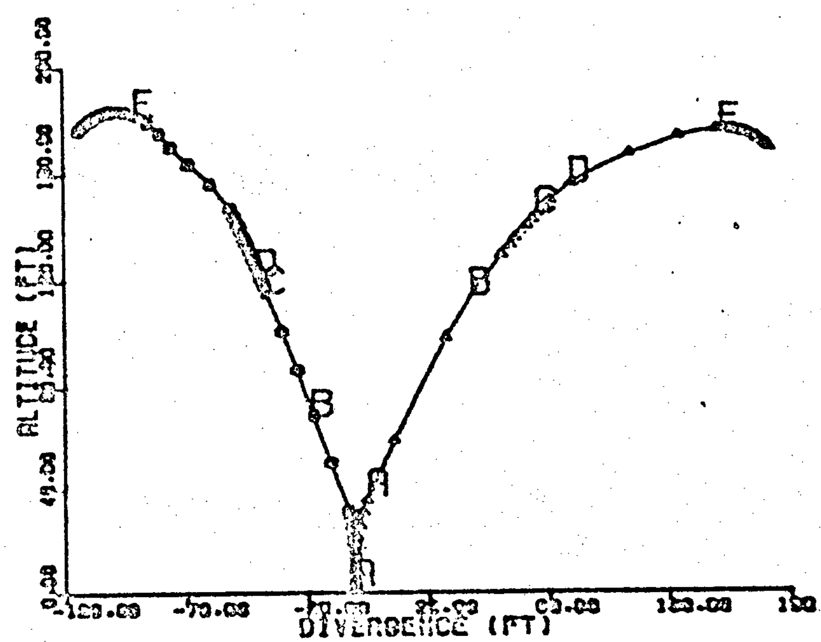


Figure D-1

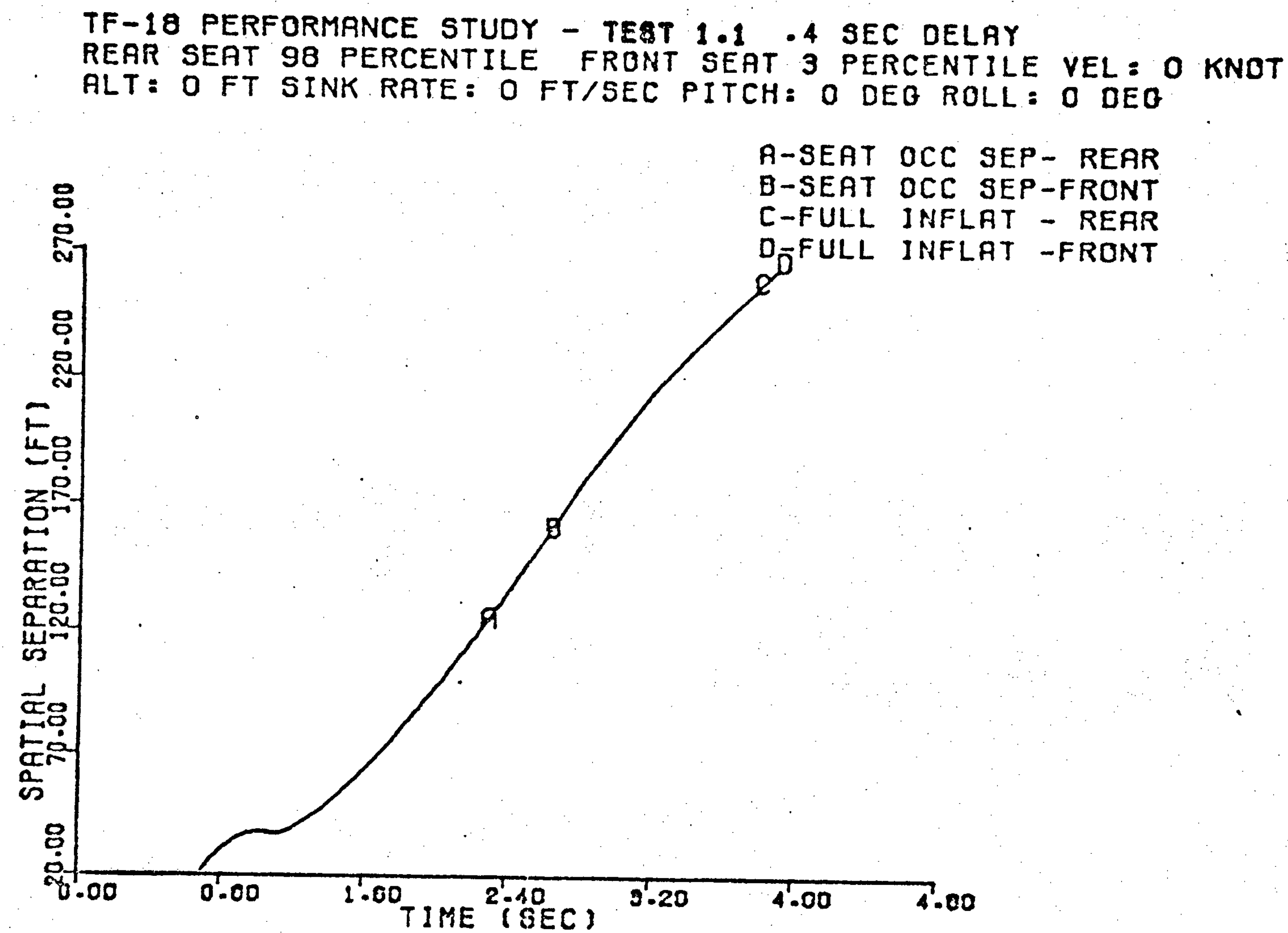

TF-18 PERFORMANCE STUDY - TEST 1.1 .4 SEC DELAY
REAR SEAT 98 PERCENTILE FRONT SEAT 3 PERCENTILE VEL: 0 KNOT
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
20.00
70.00
120.00
170.00
220.00
270.00
0.00
0.00
1.60
2.40
3.20
4.00
4.00
TIME (SEC)

Figure D-2

TF-18 PERFORMANCE STUDY - TEST 1.2 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 200 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

○ REAR SEAT
△ FRONT SEAT

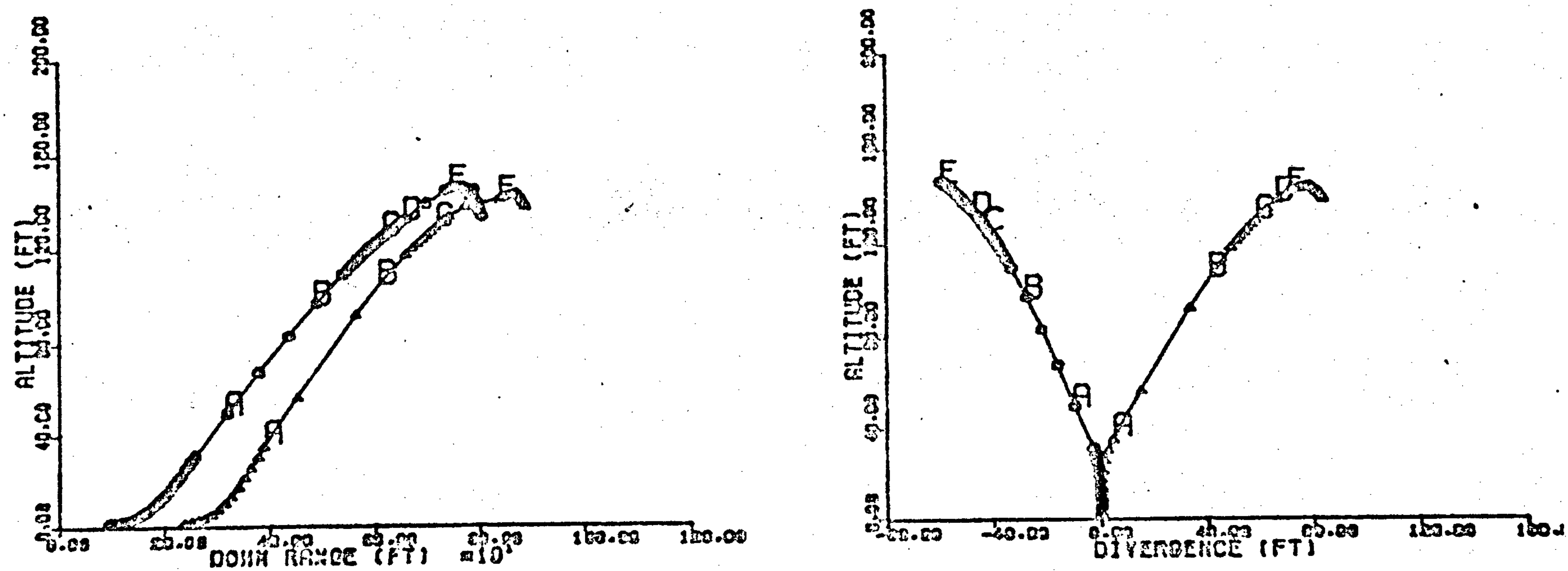


Figure D-3

TF-18 PERFORMANCESTUDY - TEST 1.2 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 200 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

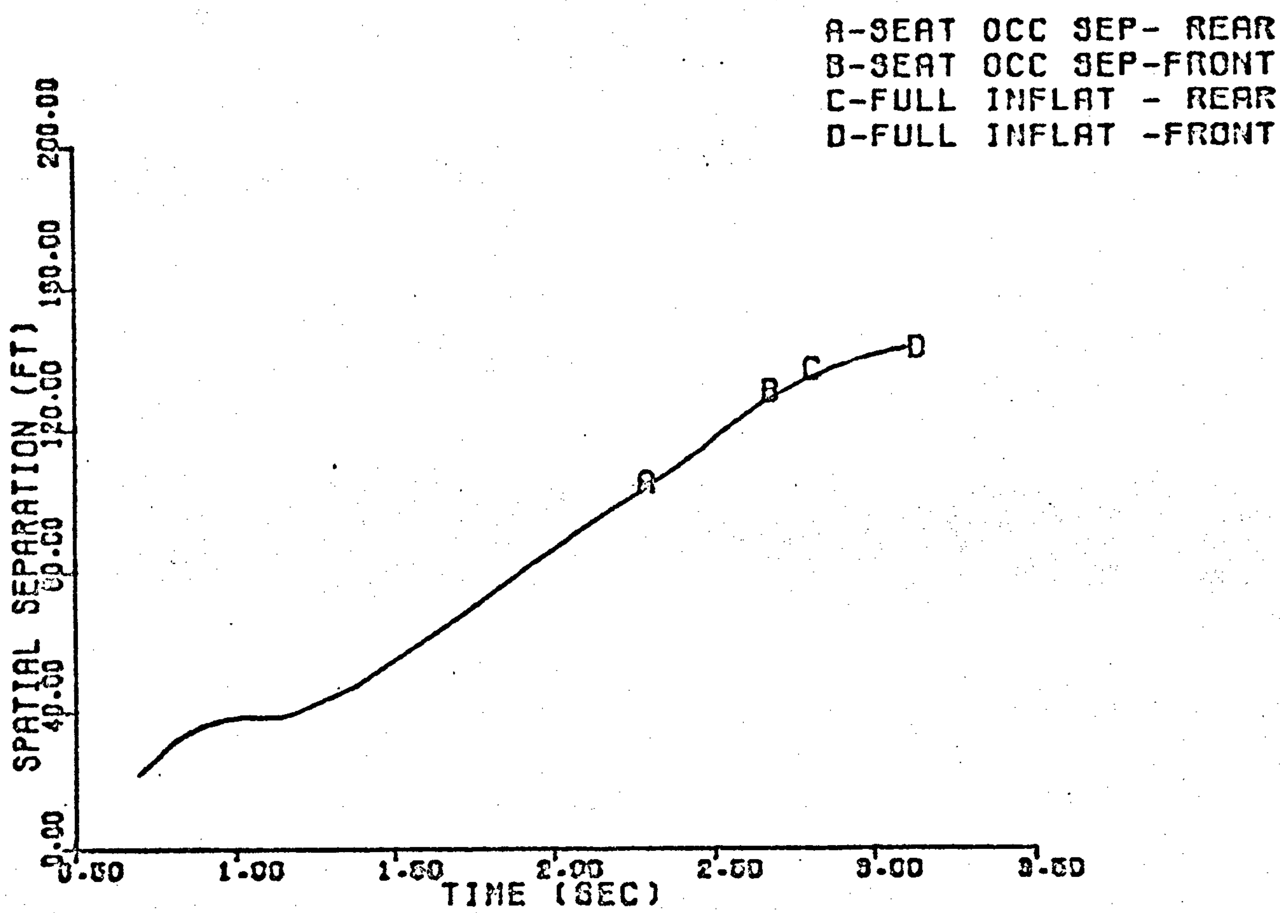


Figure D-4

TF-18 PERFORMANCE STUDY - TEST 1.3 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 600 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

O REAR SEAT
△ FRONT SEAT

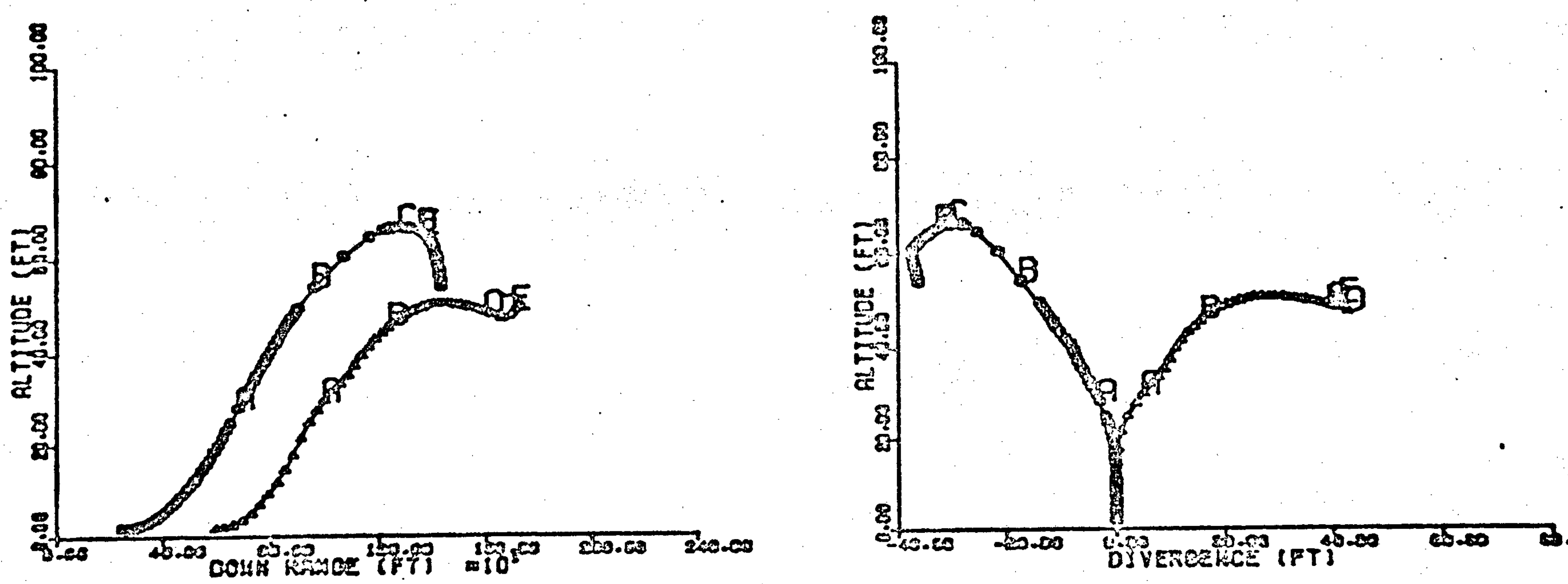


Figure D-5

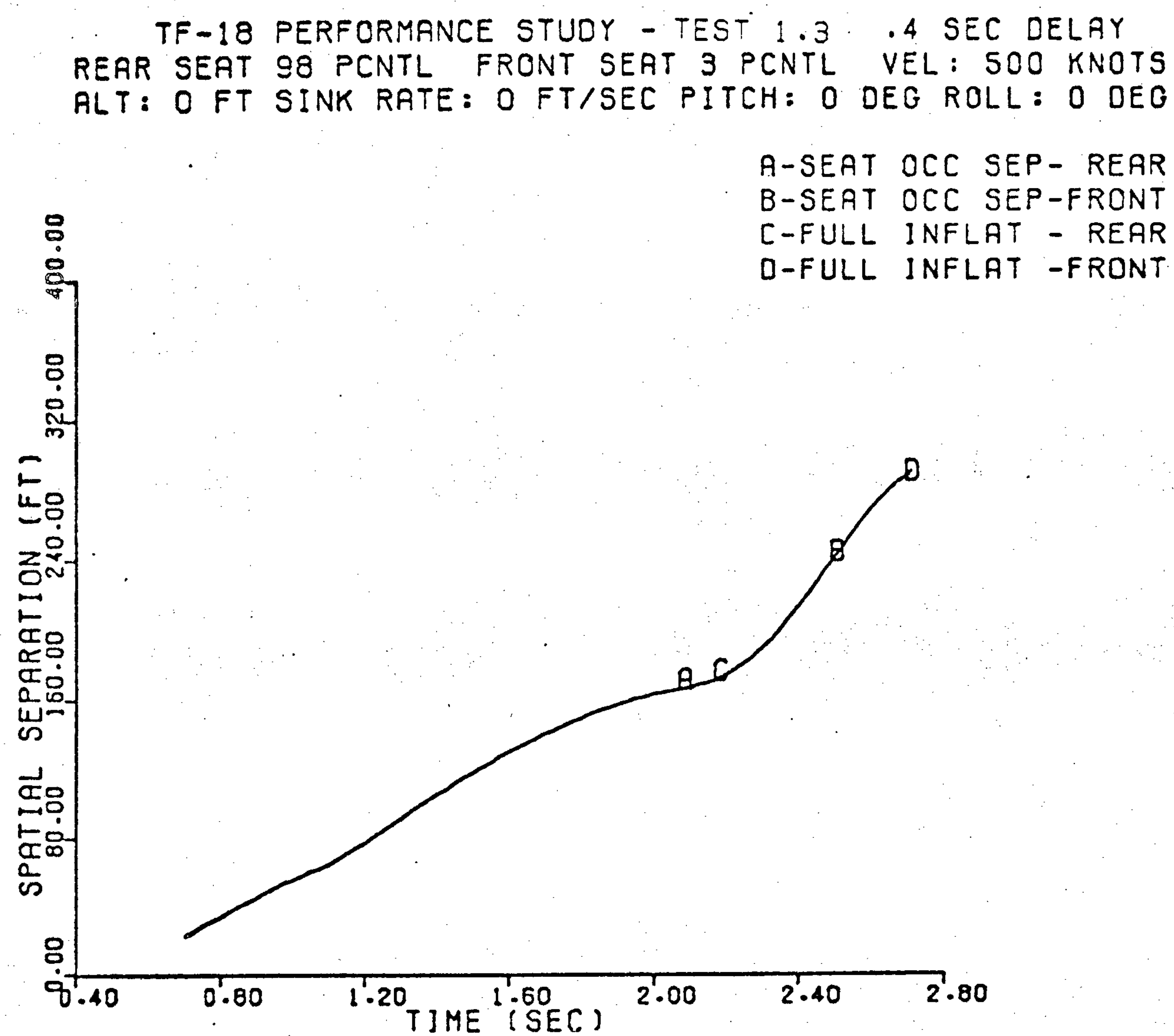

TF-18 PERFORMANCE STUDY - TEST 1.3 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 500 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
80.00
160.00
240.00
320.00
400.00
0.40
0.80
1.20
1.60
2.00
2.40
2.80
TIME (SEC)
A
B
C
D

Figure D-6

TF-18 PERFORMANCE STUDY - TEST 1.4 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 100 KNOTS
ALT: 214 FT SINK RATE: 33.33 FT/SEC PITCH: 0 DEG ROLL: 90 DEG

O REAR SEAT
Δ FRONT SEAT

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

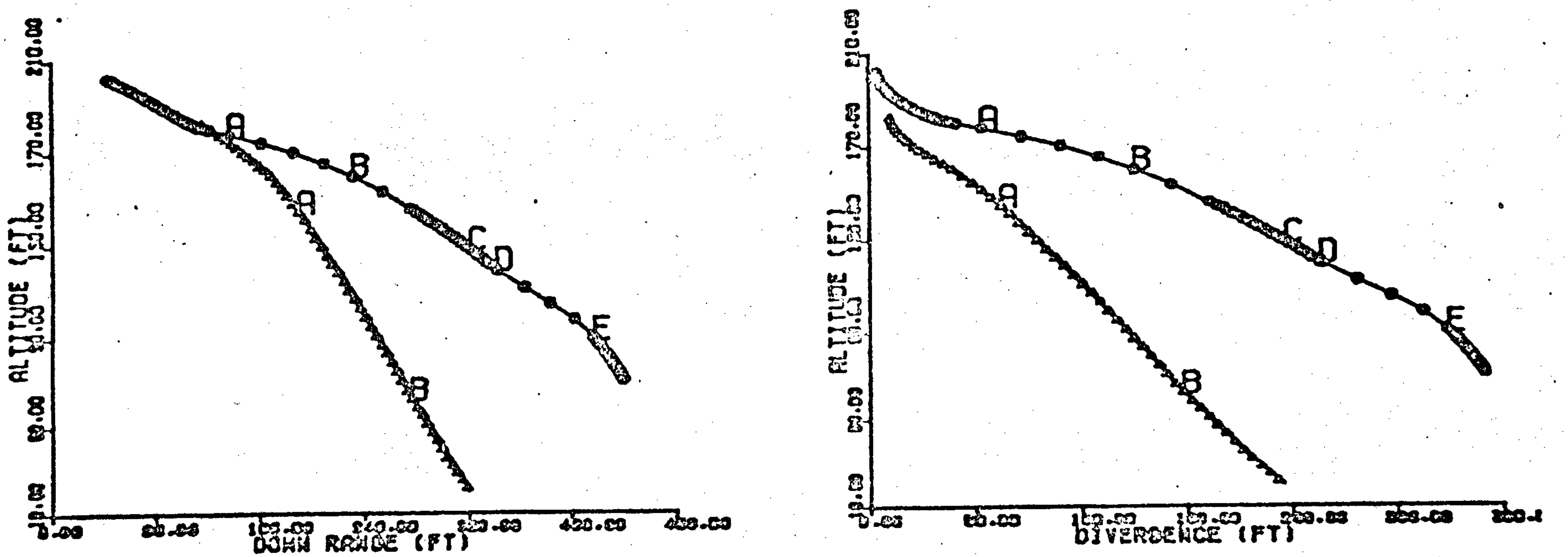


Figure D-7

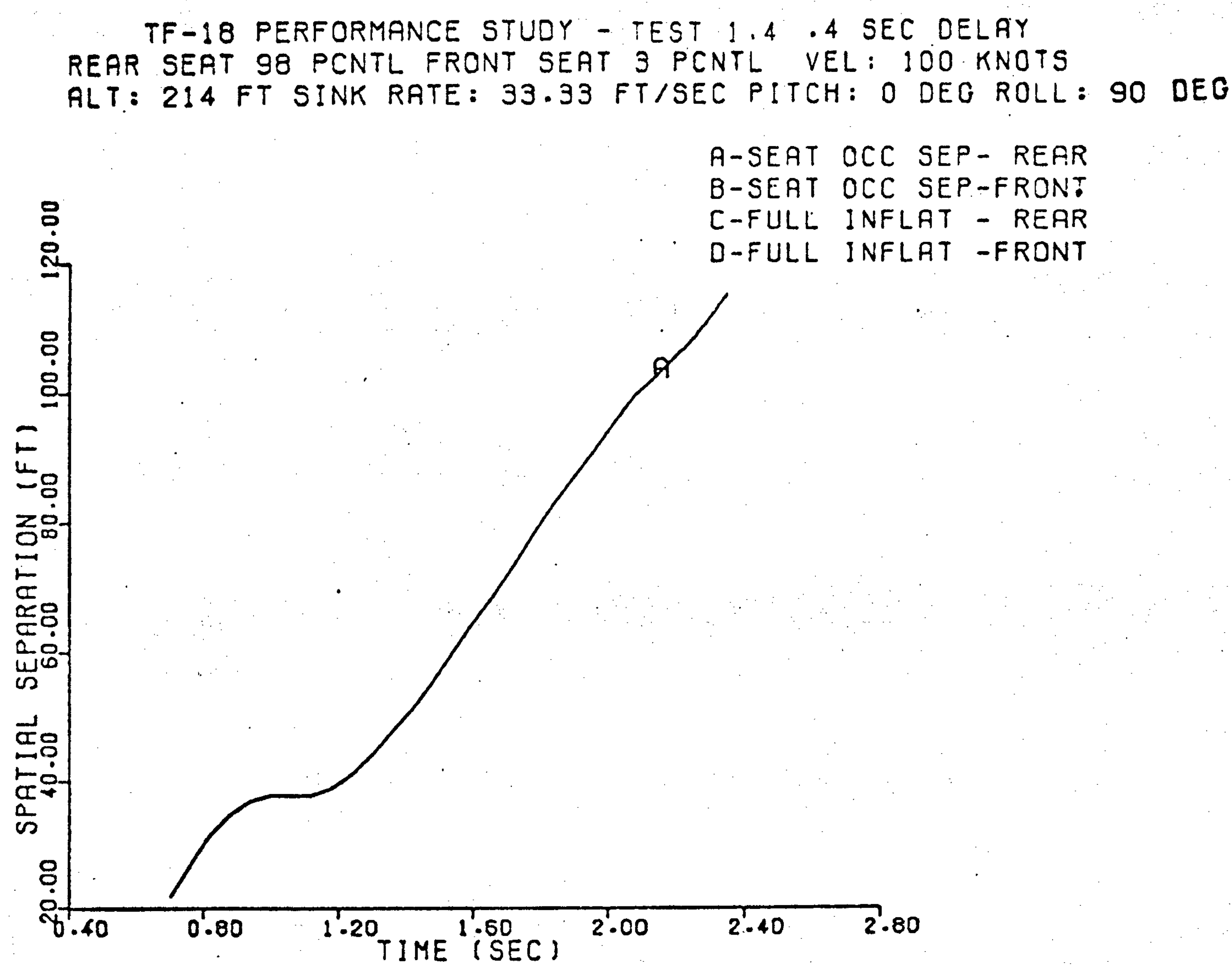
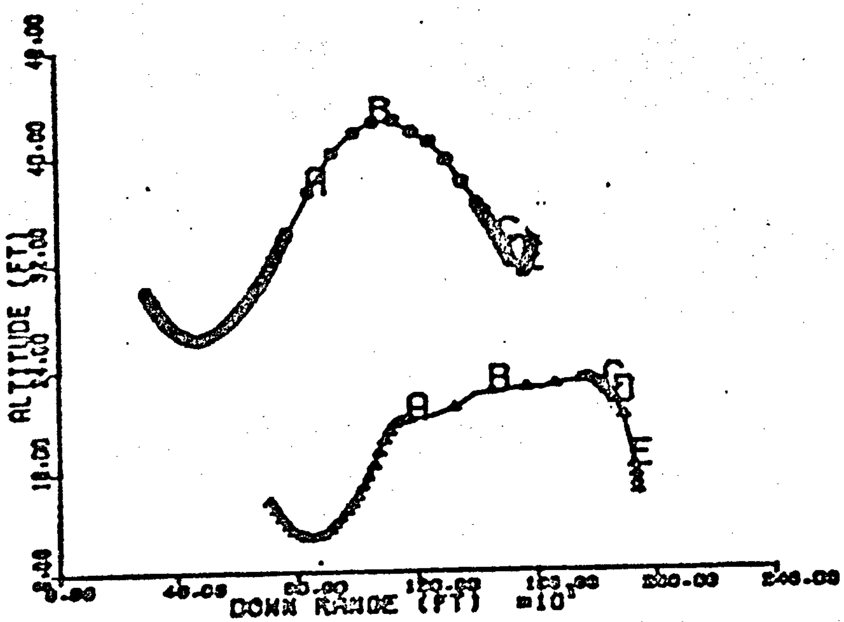

TF-18 PERFORMANCE STUDY - TEST 1.4 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 100 KNOTS
ALT: 214 FT SINK RATE: 33.33 FT/SEC PITCH: 0 DEG ROLL: 90 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
A
SPATIAL SEPARATION (FT)
20.00
40.00
60.00
80.00
100.00
120.00
0.40
0.80
1.20
1.60
2.00
2.40
2.80
TIME (SEC)

Figure D-8

TF-18 PERFORMANCE STUDY - TEST 1.5 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 600 KNOTS
ALT: 40 FT SINK RATE: 40 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

○ REAR SEAT
△ FRONT SEAT



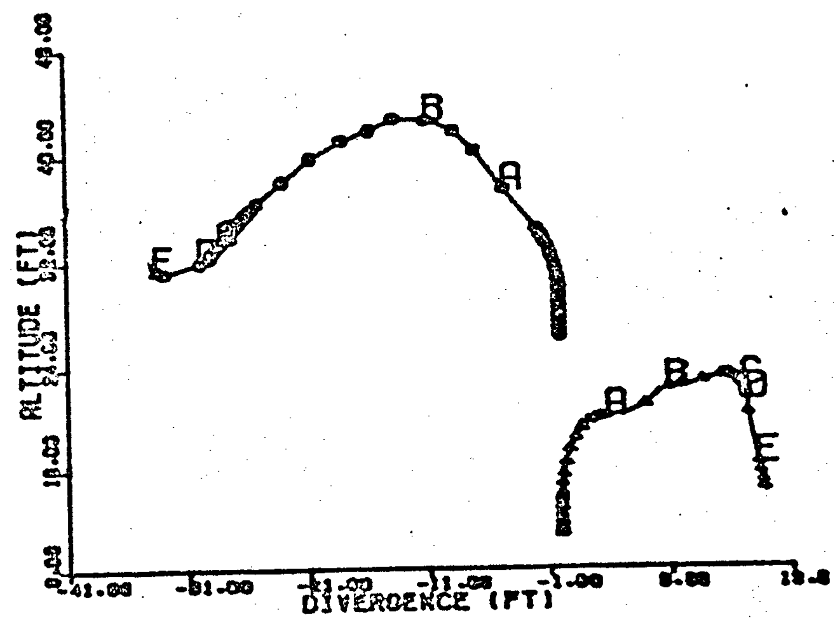


Figure D-9

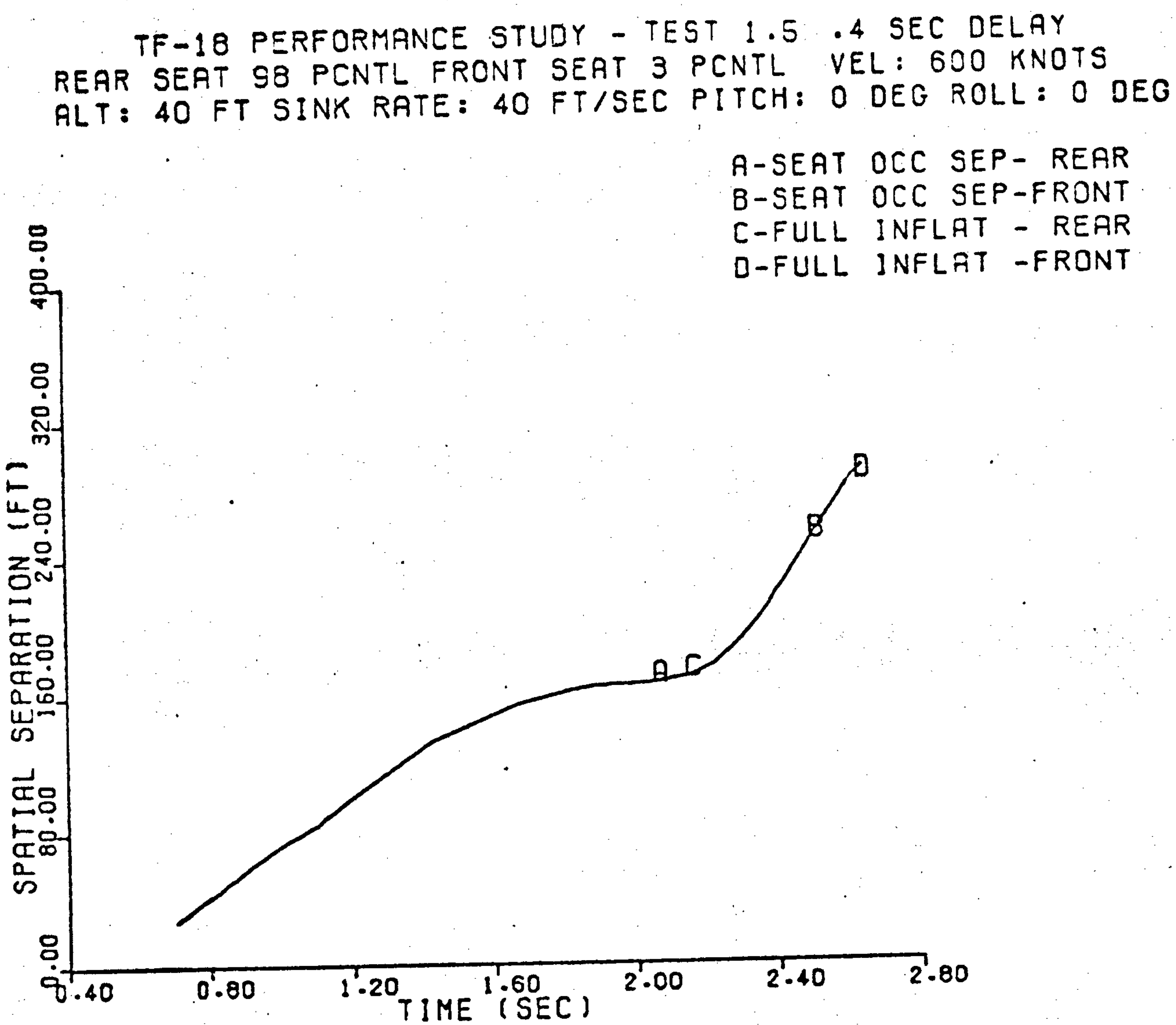

TF-18 PERFORMANCE STUDY - TEST 1.5 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 600 KNOTS
ALT: 40 FT SINK RATE: 40 FT/SEC PITCH: 0 DEG ROLL: 0 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
80.00
160.00
240.00
320.00
400.00
0.40
0.80
1.20
1.60
2.00
2.40
2.80
TIME (SEC)
A
B
C
D

Figure D-10

TF-18 PERFORMANCE STUDY - TEST 1.6 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 100 KNOTS
ALT: 40 FT SINK RATE: 33.33 FT/SEC PITCH: 0 DEG ROLL: 45 DEG

O REAR SEAT
▲ FRONT SEAT

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

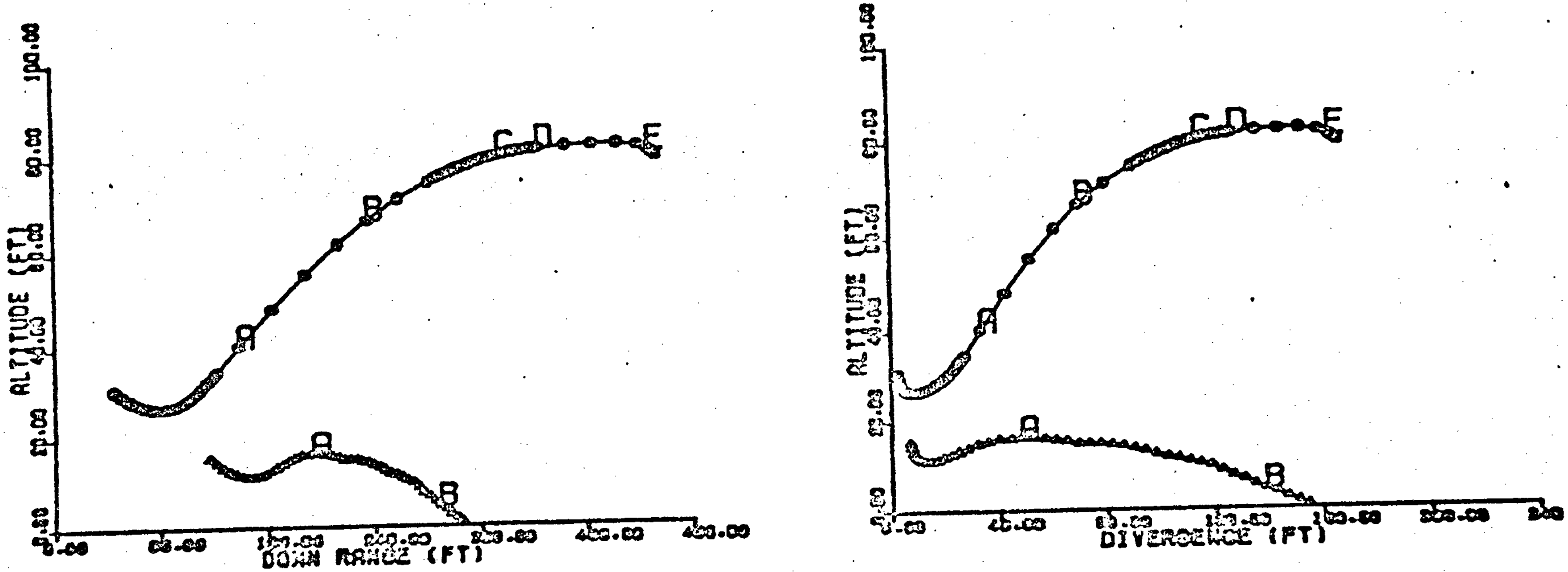


Figure D-11

TF-18 PERFORMANCE STUDY - TEST 1.8. .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 100 KNOTS
ALT: 40 FT SINK RATE: 33.33 FT/SEC PITCH: 0 DEG ROLL: 45 DEG

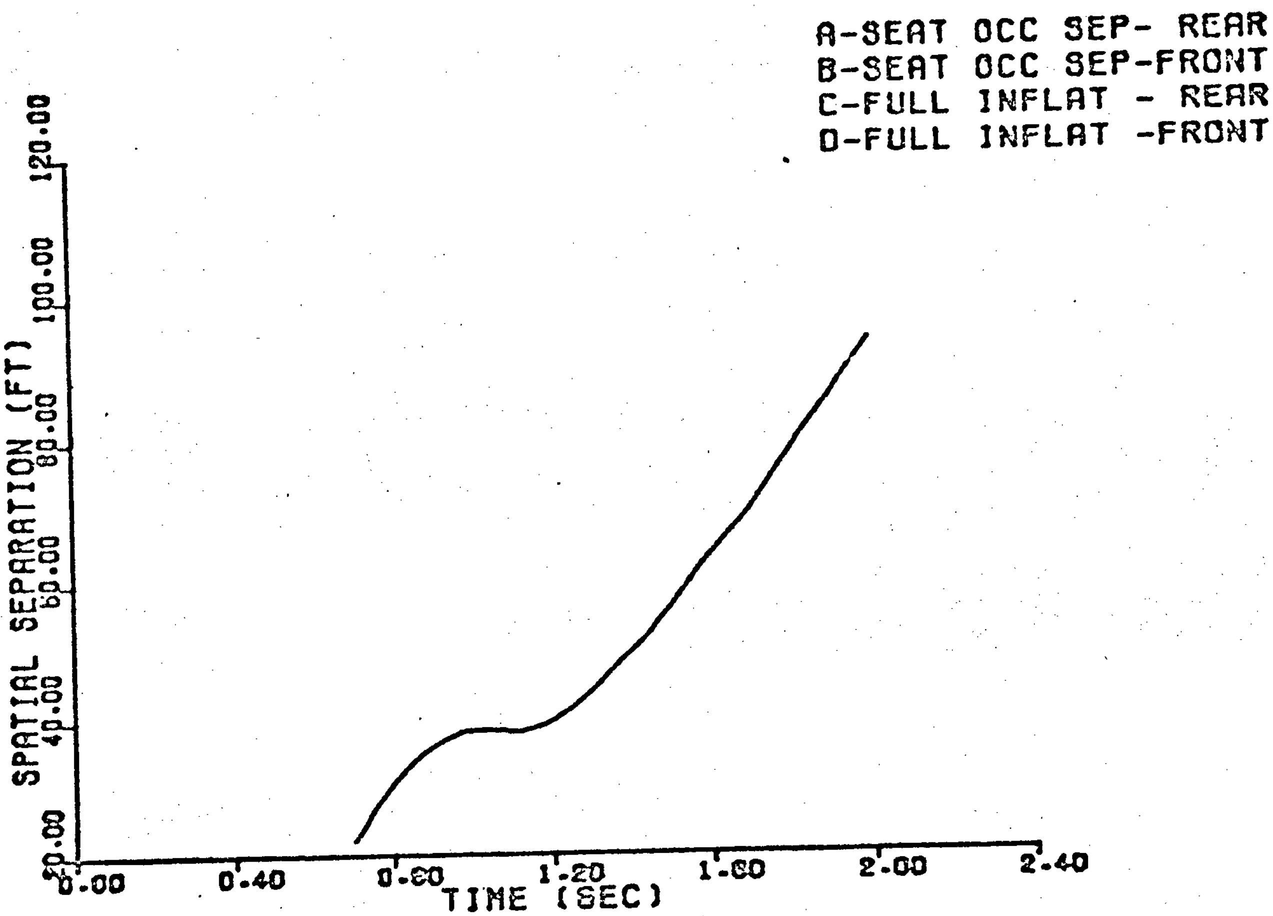


Figure D-12

TF-18 PERFORMANCE STUDY - TEST 1.7 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 130 KNOTS
ALT: 245 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 120 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

⊙ REAR SEAT
▲ FRONT SEAT

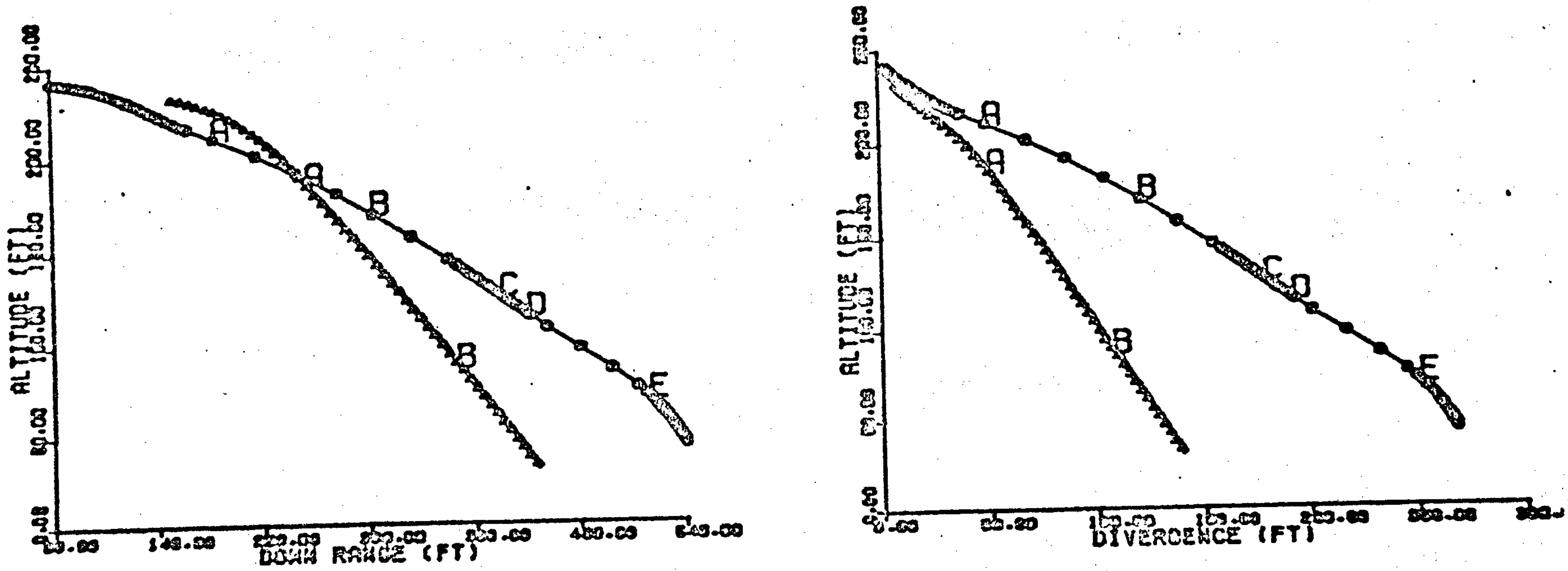


Figure D-13

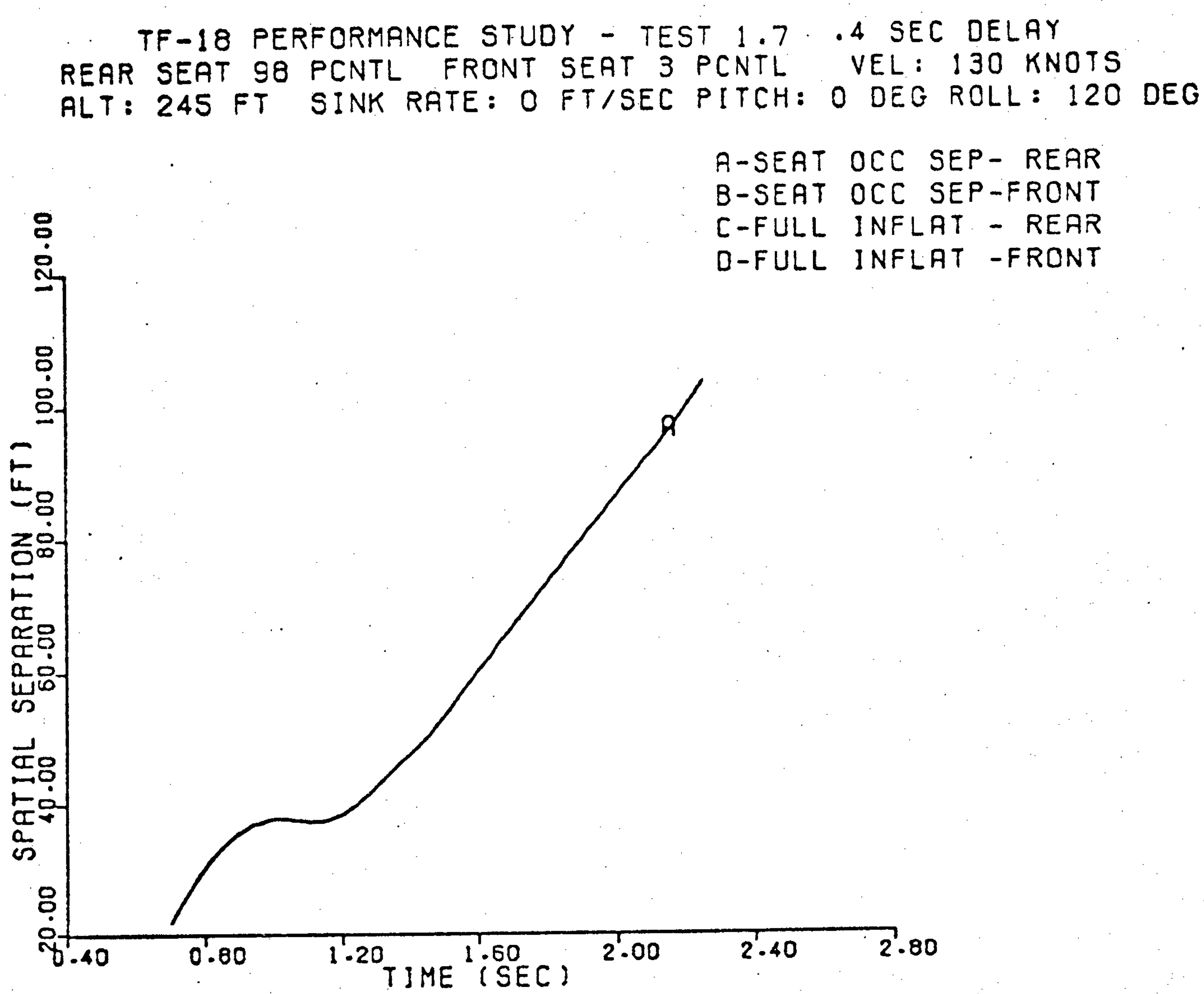
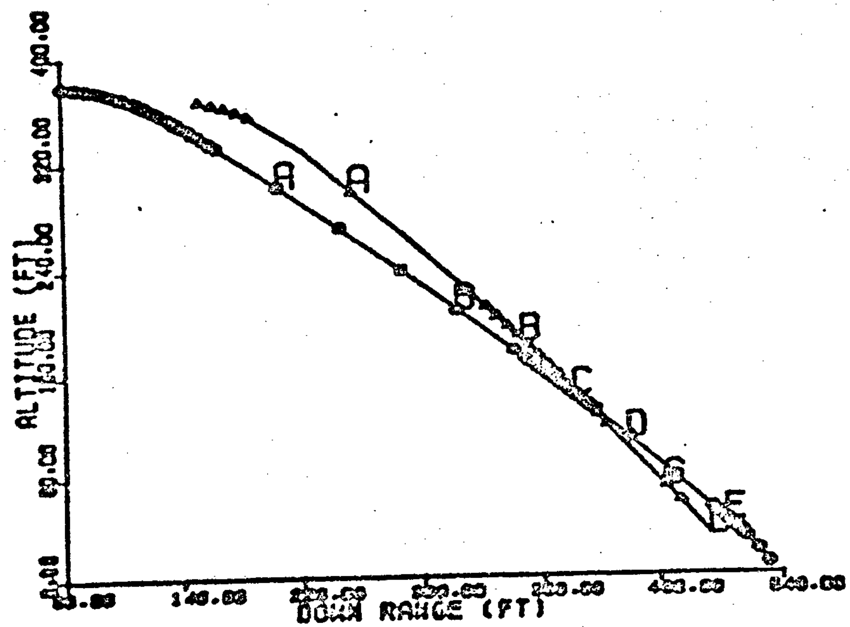

TF-18 PERFORMANCE STUDY - TEST 1.7 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 130 KNOTS
ALT: 245 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 120 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
20.00
40.00
60.00
80.00
100.00
120.00
0.40
0.80
1.20
1.60
2.00
2.40
2.80
TIME (SEC)
A

Figure D-14

TF-18 PERFORMANCE STUDY - TEST 1.8 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 130 KNOTS
ALT: 384 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 180 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

○ REAR SEAT
△ FRONT SEAT



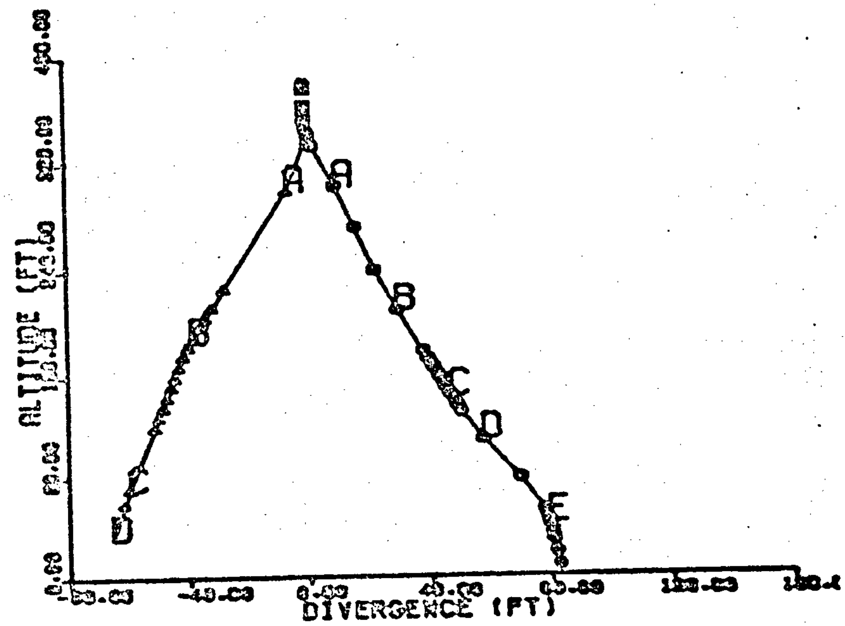


Figure D-15

TF-18 PERFORMANCE STUDY - TEST 1.8 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 130 KNOTS
ALT: 384 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 180 DEG

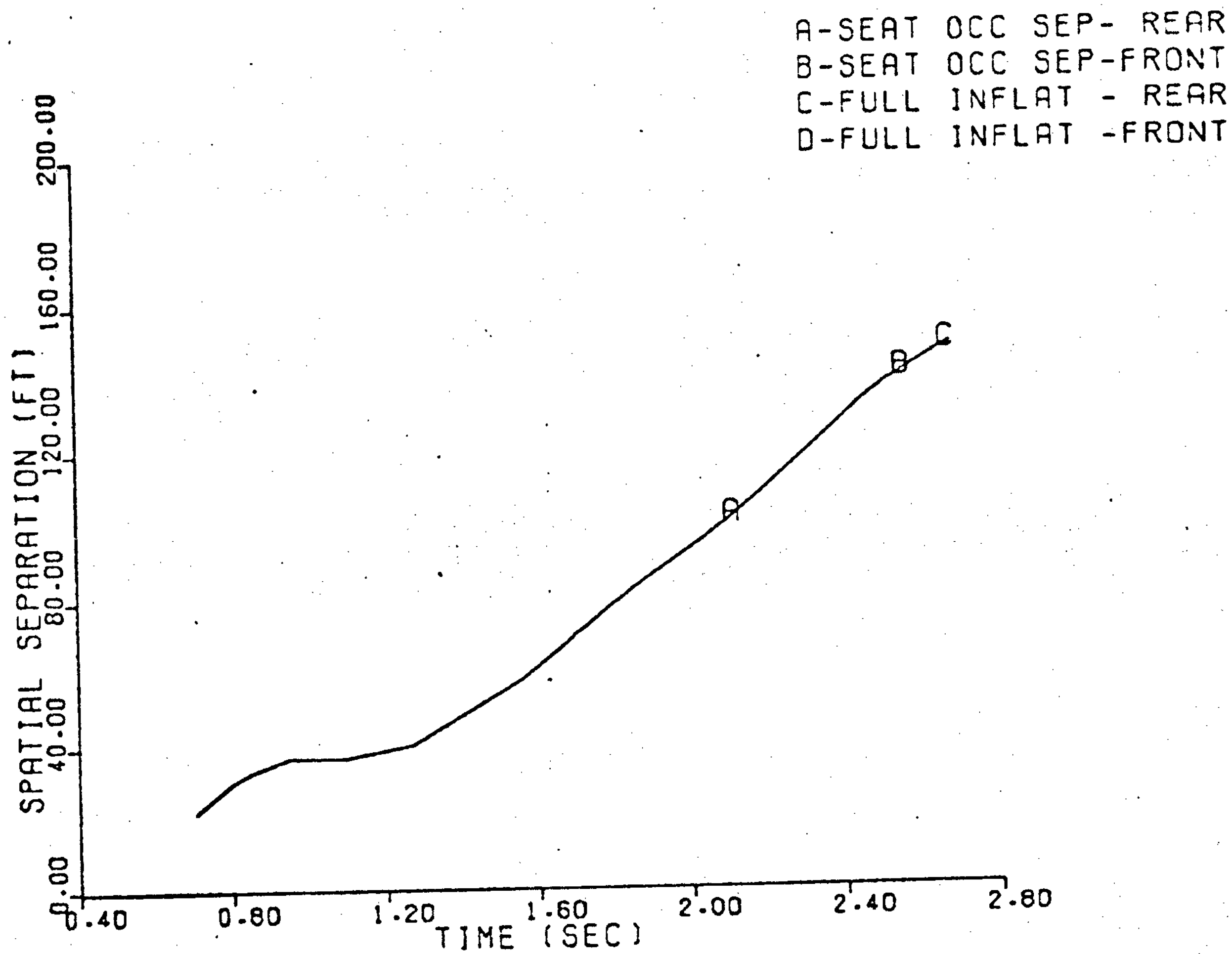


Figure D-16

TF-18 PERFORMANCE STUDY - TEST 1.9 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 130 KNOTS
ALT: 55 FT SINK RATE: 50 FT/SEC PITCH: -15 DEG ROLL: 0 DEG

○ REAR SEAT
△ FRONT SEAT

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

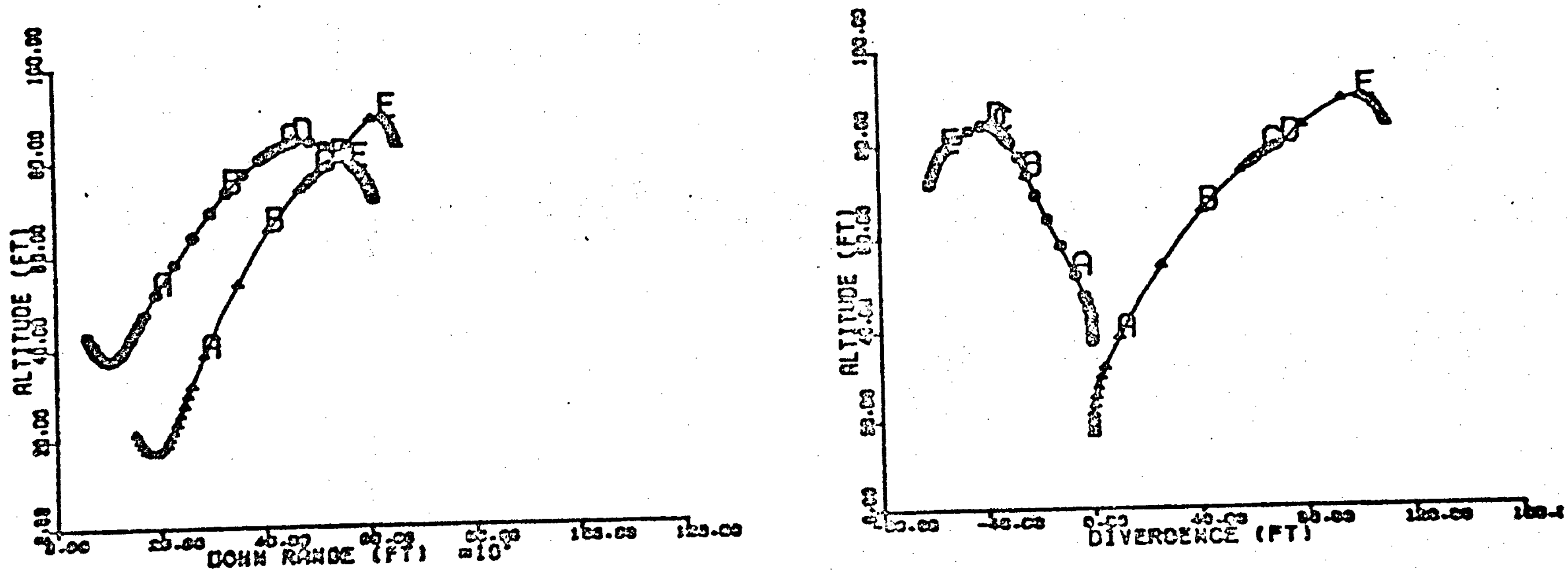


Figure D-17

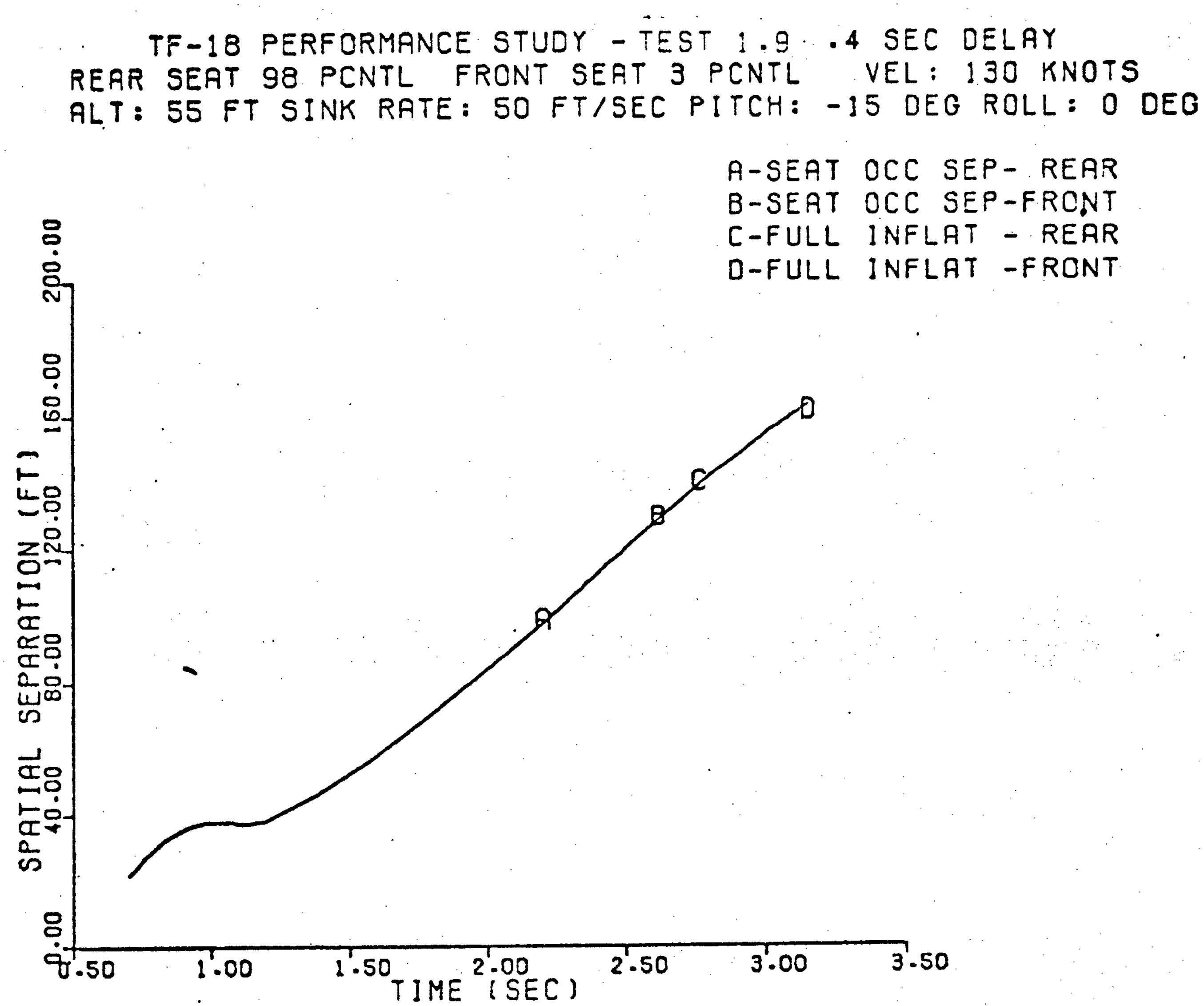

TF-18 PERFORMANCE STUDY - TEST 1.9 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 130 KNOTS
ALT: 55 FT SINK RATE: 50 FT/SEC PITCH: -15 DEG ROLL: 0 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
40.00
80.00
120.00
160.00
200.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
TIME (SEC)
A
B
C
D

Figure D-18

TF-18 PERFORMANCE STUDY - TEST 1.10 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 130 KNOTS
ALT: 20 FT SINK RATE: 20 FT/SEC PITCH: -5 DEG ROLL: 0 DEG

○ REAR SEAT
△ FRONT SEAT

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

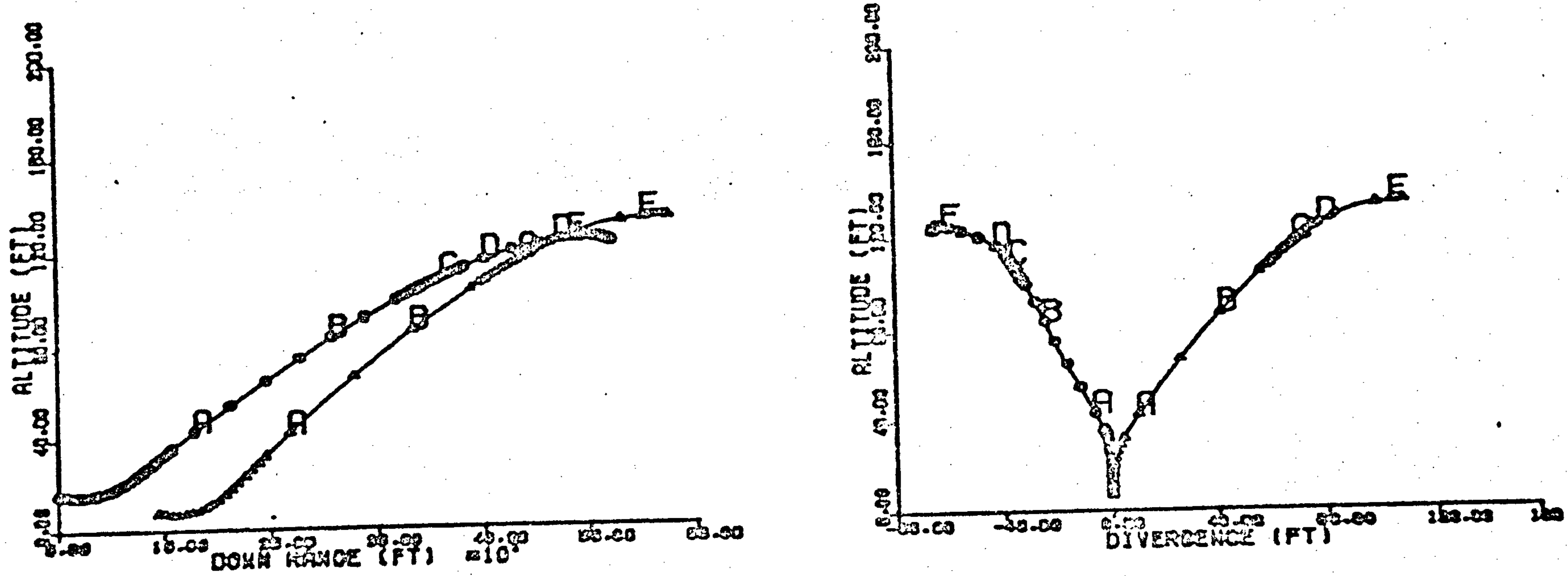


Figure D-19

TF-18 PERFORMANCE STUDY - TEST 1.10 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 130 KNOTS
ALT: 20 FT SINK RATE: 20 FT/SEC PITCH: -5 DEG ROLL: 0 DEG

A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT

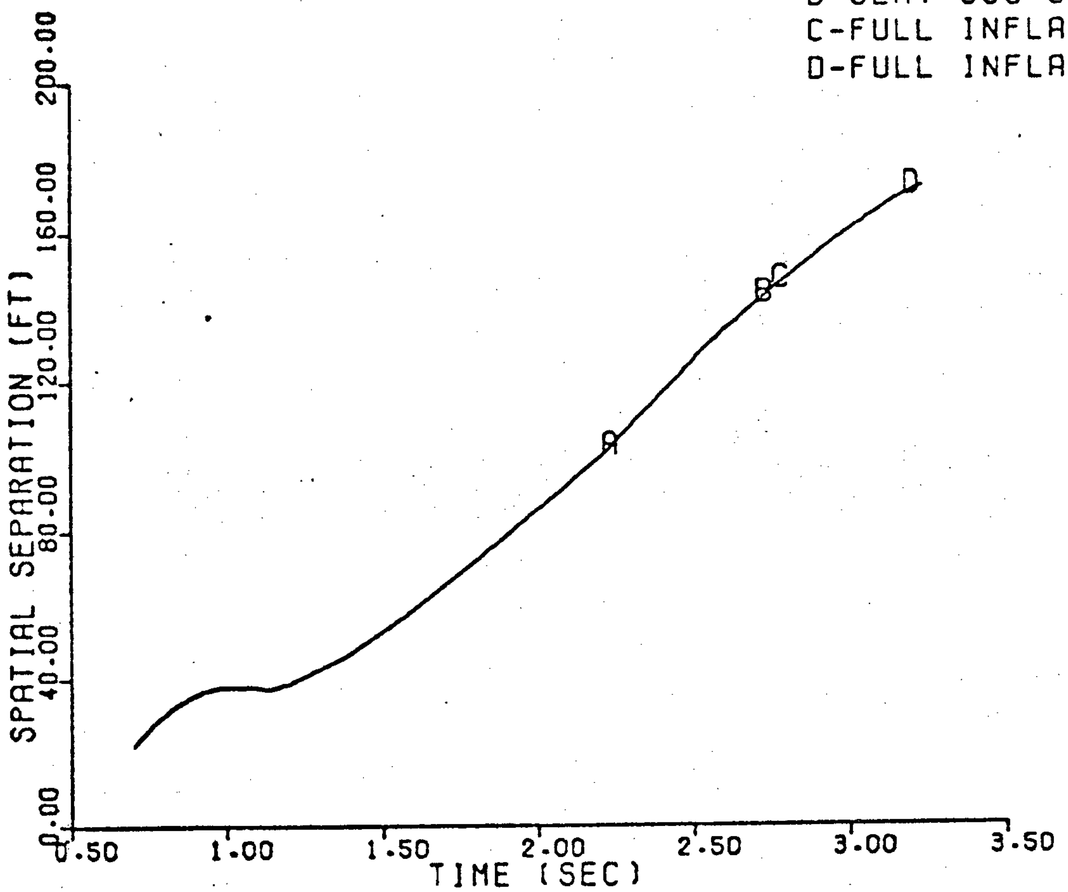


Figure D-20

TF-18 PERFORMANCE STUDY - TEST 1.11 .2 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 0 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

○ REAR SEAT
△ FRONT SEAT

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

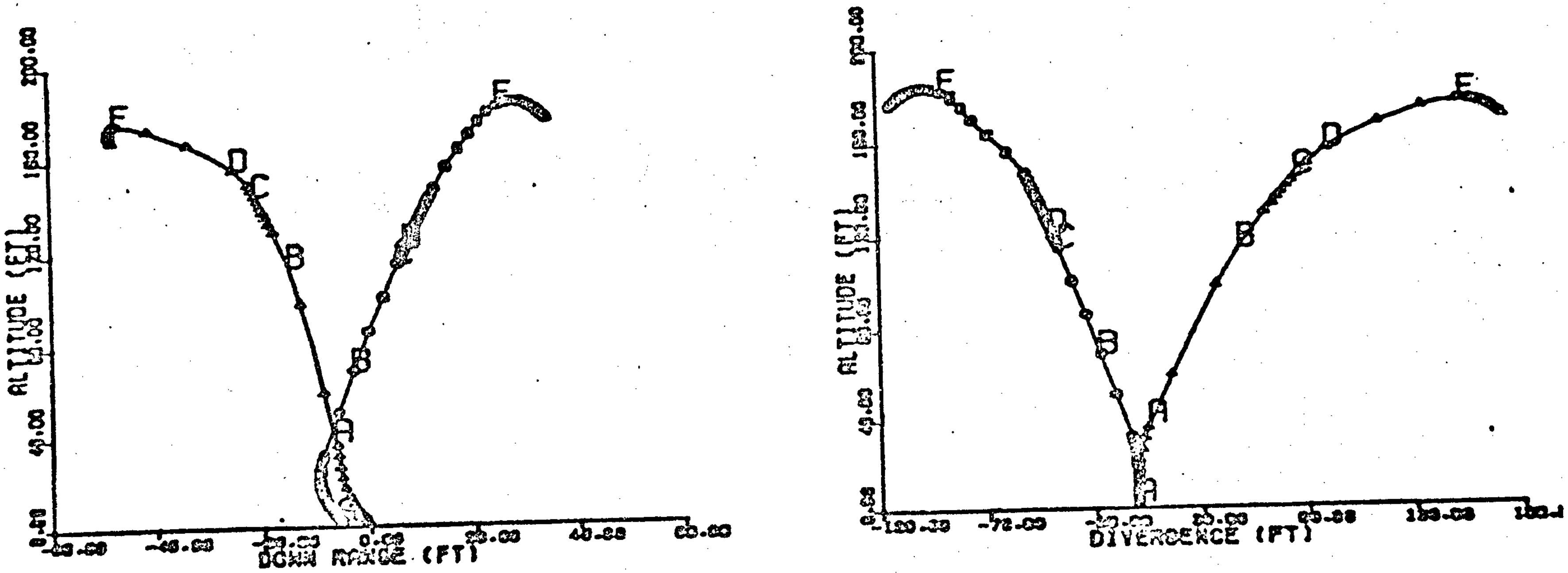


Figure D-21

TF-18 PERFORMANCE STUDY - TEST 1.11 .2 SEC DELAY
REAR SEAT 98 PERCENTILE FRONT SEAT 3 PERCENTILE VEL: 0 KNOT
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT

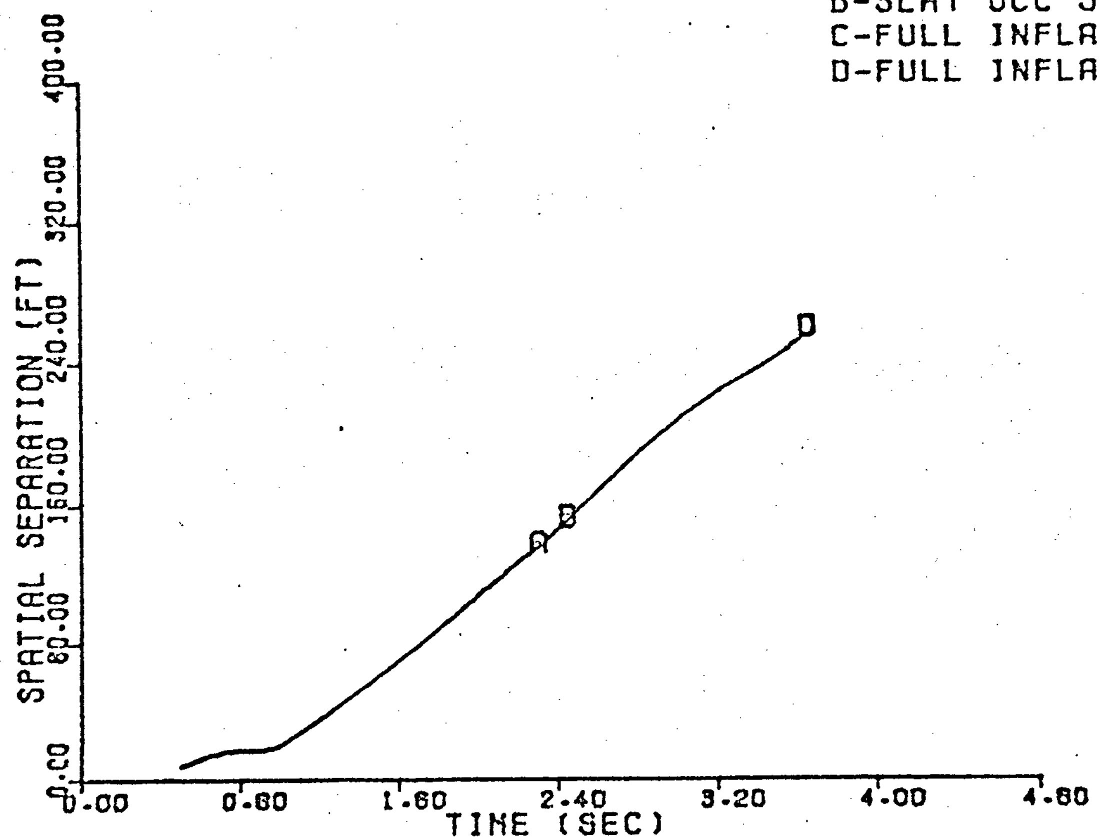


Figure D-22

TF-18 PERFORMANCE STUDY - TEST 1.12 .2 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 200 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

O REAR SEAT
△ FRONT SEAT

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

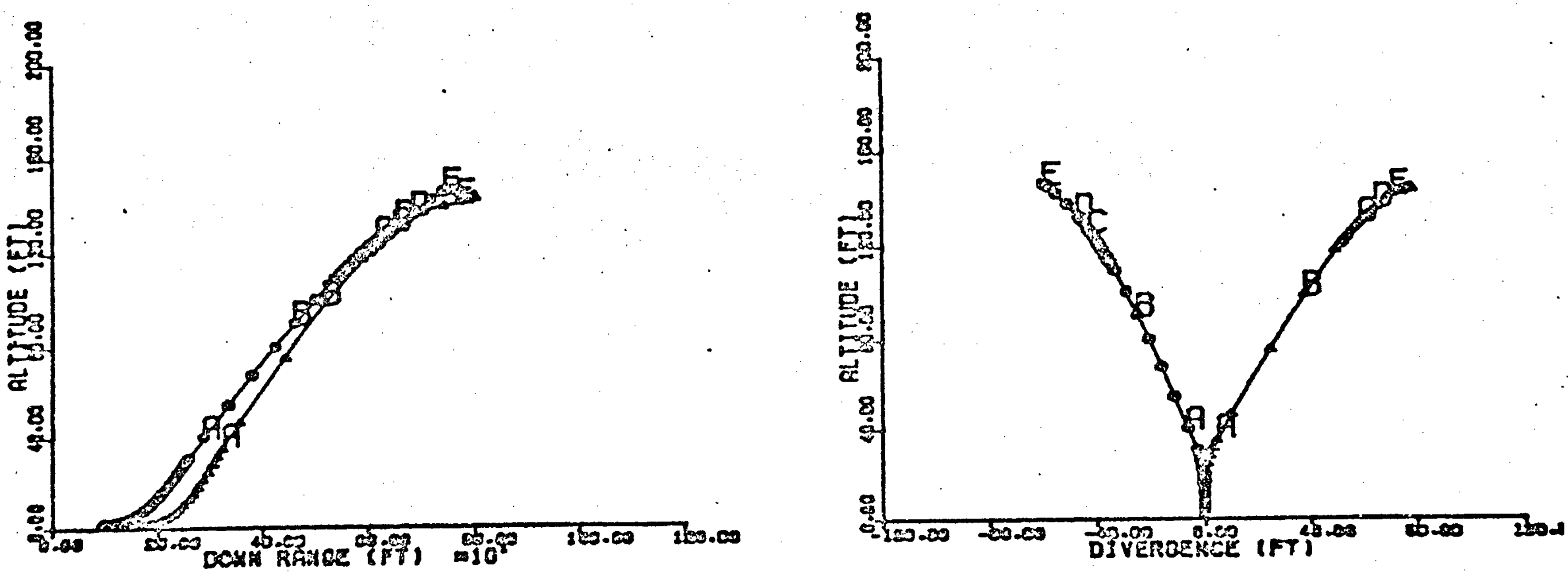


Figure D-23

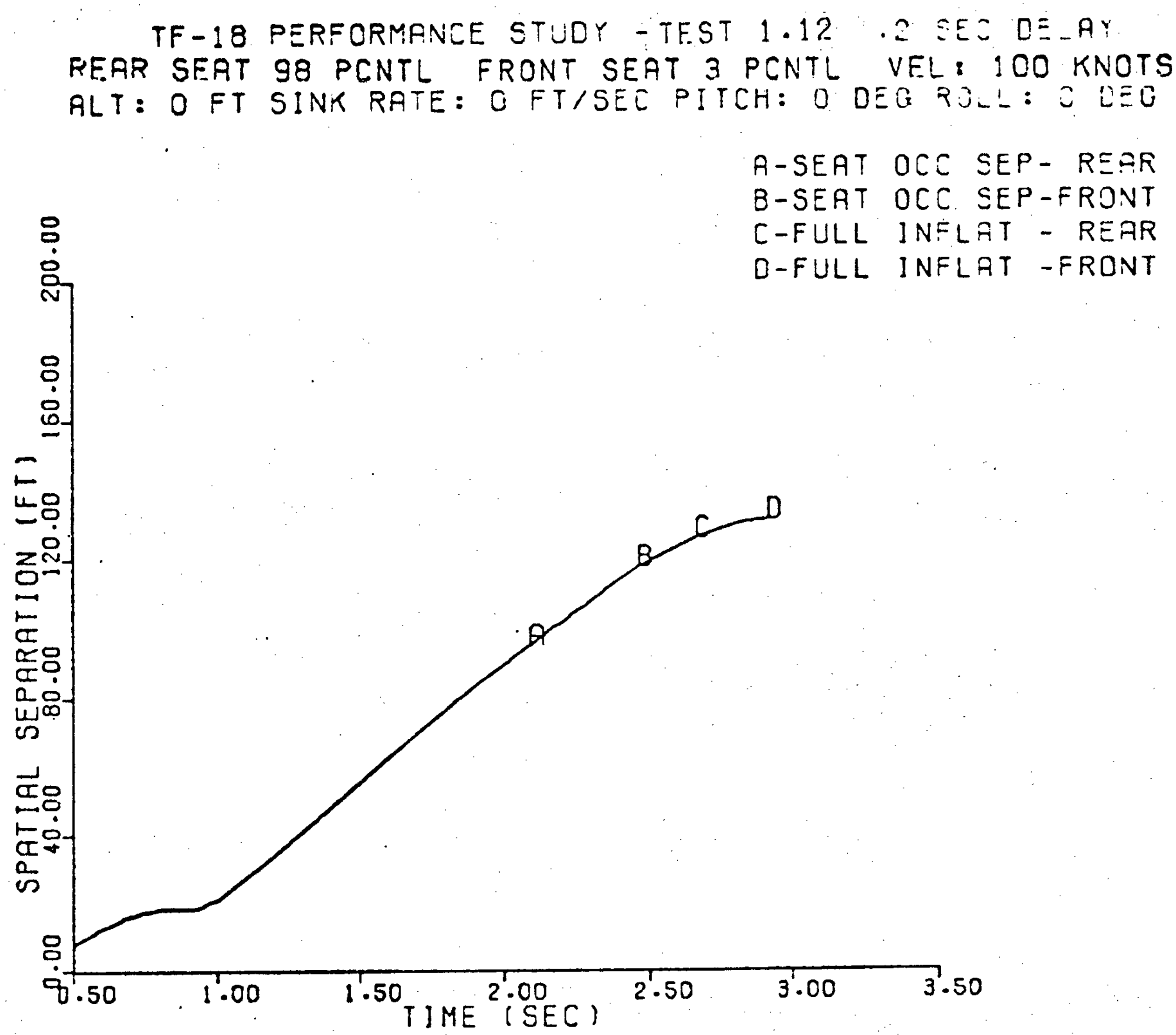
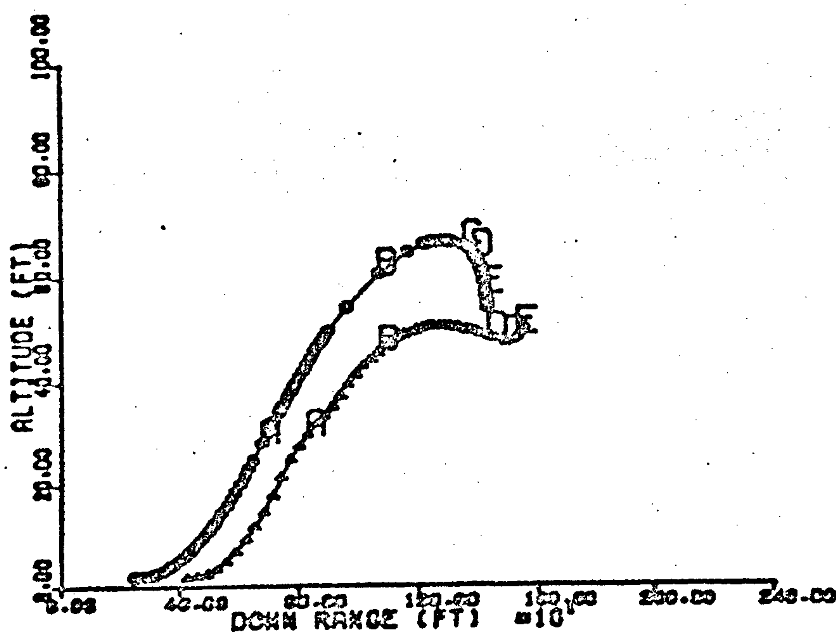

TF-18 PERFORMANCE STUDY -TEST 1.12 .2 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 100 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
40.00
80.00
120.00
160.00
200.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
TIME (SEC)
A
B
C
D

Figure D-24

TF-18 PERFORMANCE STUDY - TEST 1.18 .2 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 500 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

○ REAR SEAT
△ FRONT SEAT

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION



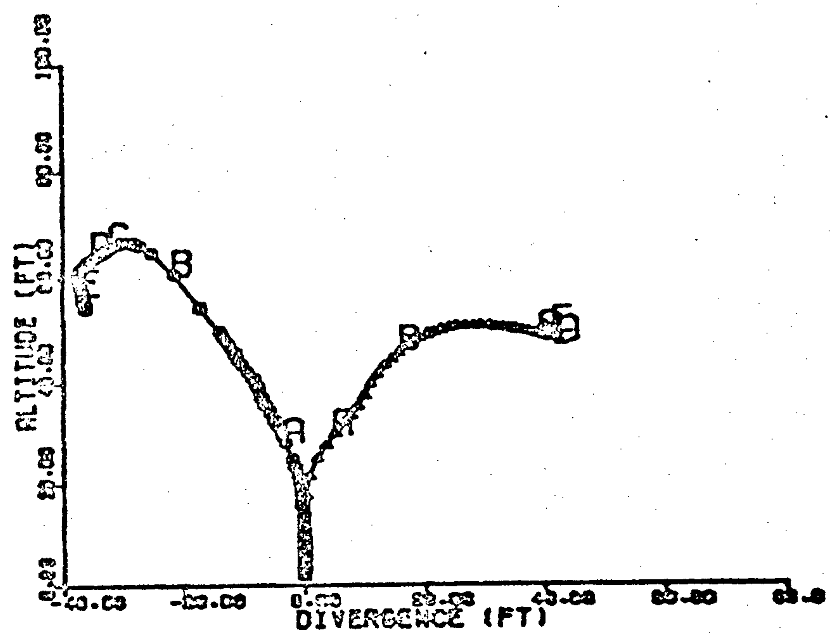


Figure D-25

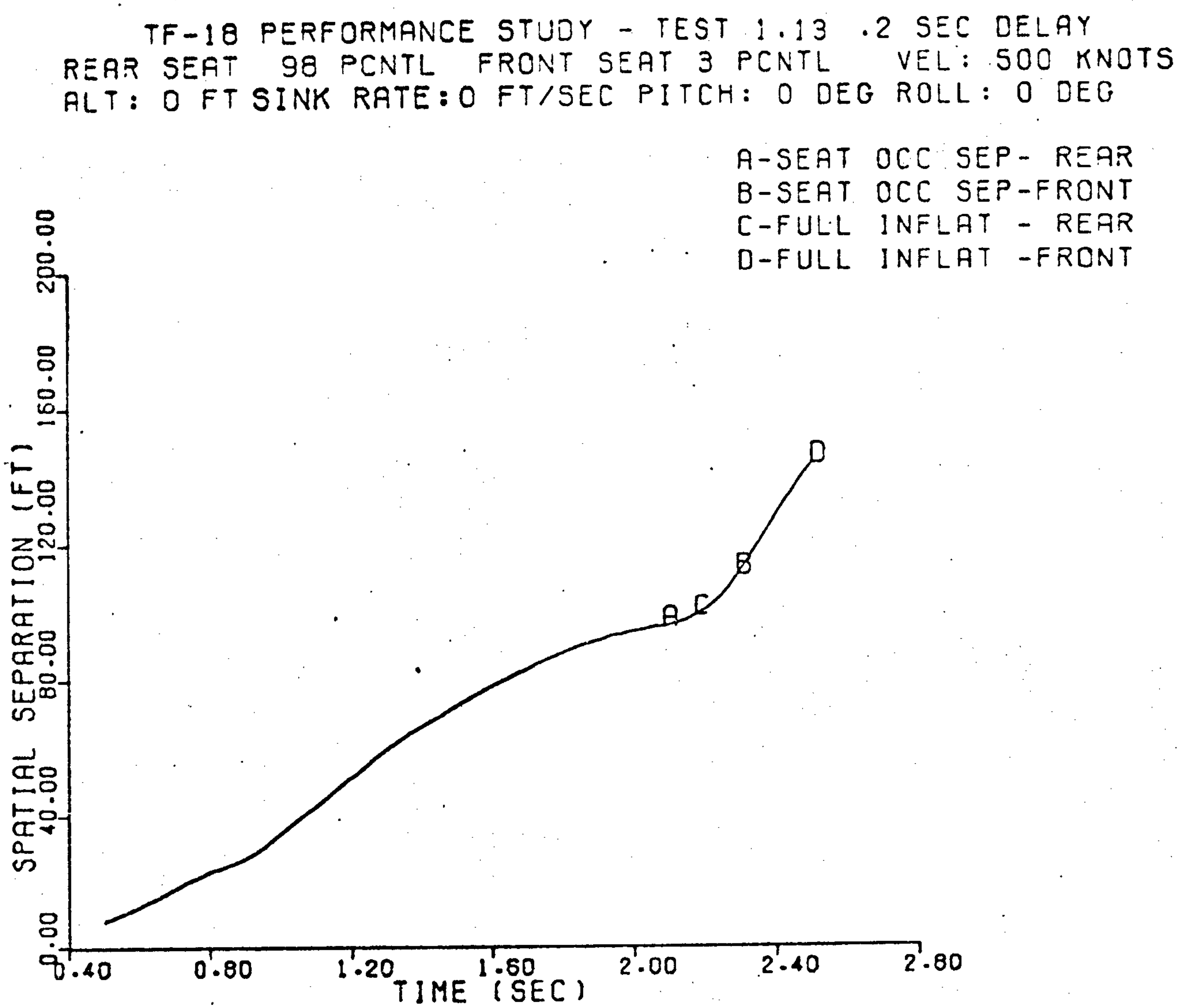

TF-18 PERFORMANCE STUDY - TEST 1.13 .2 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 500 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
40.00
80.00
120.00
160.00
200.00
0.40
0.80
1.20
1.60
2.00
2.40
2.80
TIME (SEC)
A
B
C
D

Figure D-26

TF-18 PERFORMANCE STUDY - TEST 1.14 .2 SEC DELAY
REAR SEAT 98 PCNTL FRONT 3 PCNTL VEL: 100 KNOTS
ALT: 214 FT SINK RATE: 33.33 FT/SEC PITCH: 0 DEG ROLL: 90 DEG

O REAR SEAT
▲ FRONT SEAT

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

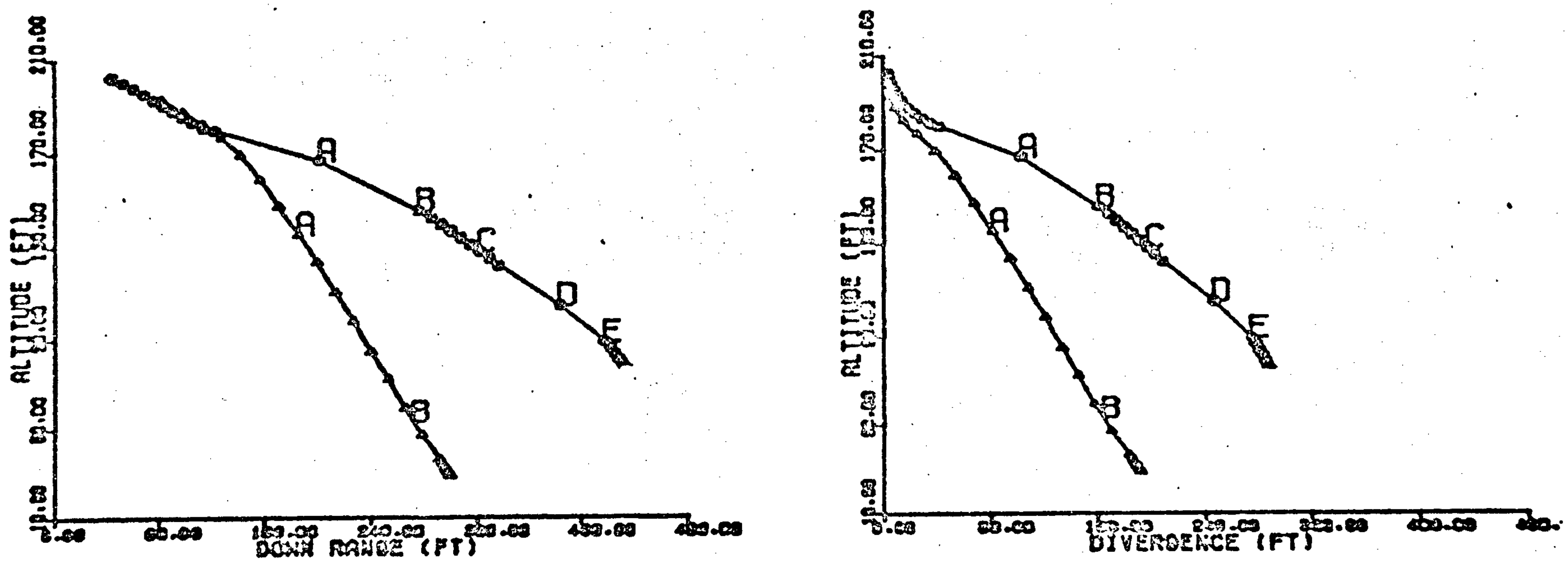


Figure D-27

TF-18 PERFORMANCE STUDY - TEST 1.14 .2 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 100 KNOTS
ALT: 214 FT SINK RATE: 33.33 FT/SEC PITCH: 0 DEG ROLL: 90 DEG

A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT

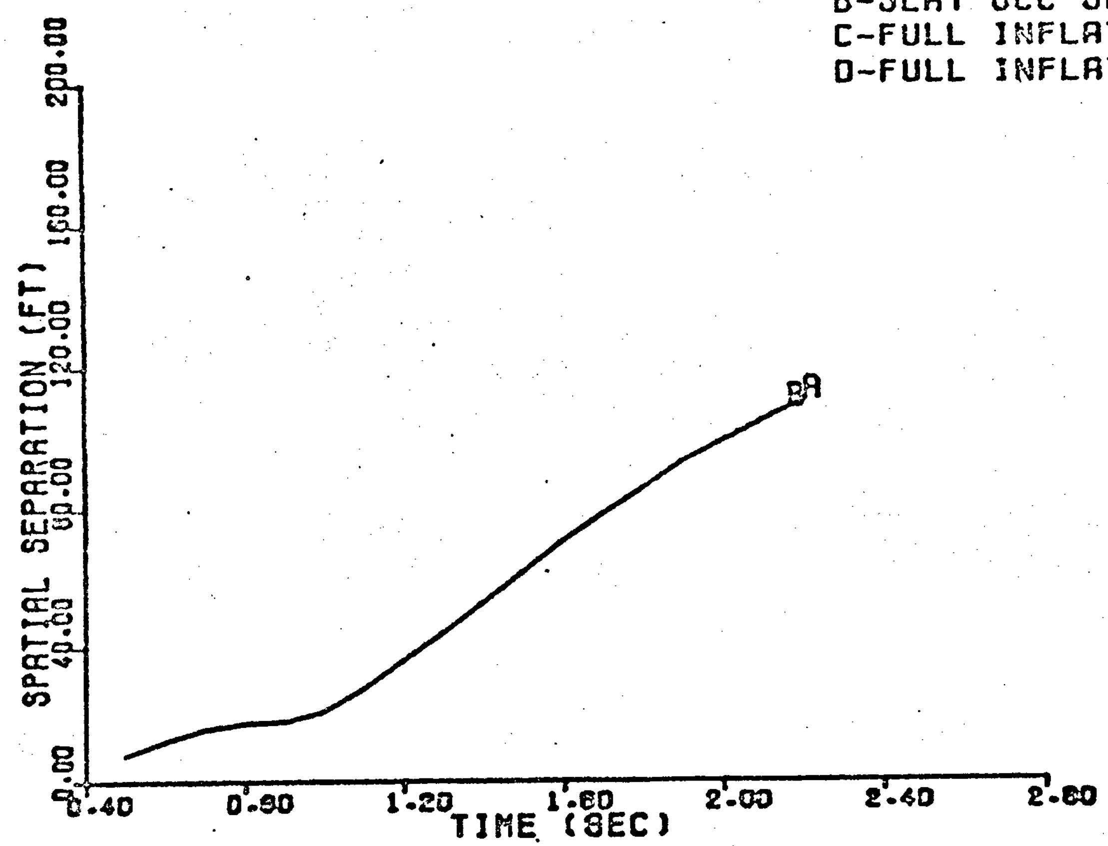


Figure D-28

TF-18 PERFORMANCE STUDY - TEST 1.15 .2 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 600 KNOTS
ALT: 40 FT SINK RATE: 40 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

○ REAR SEAT
△ FRONT SEAT

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

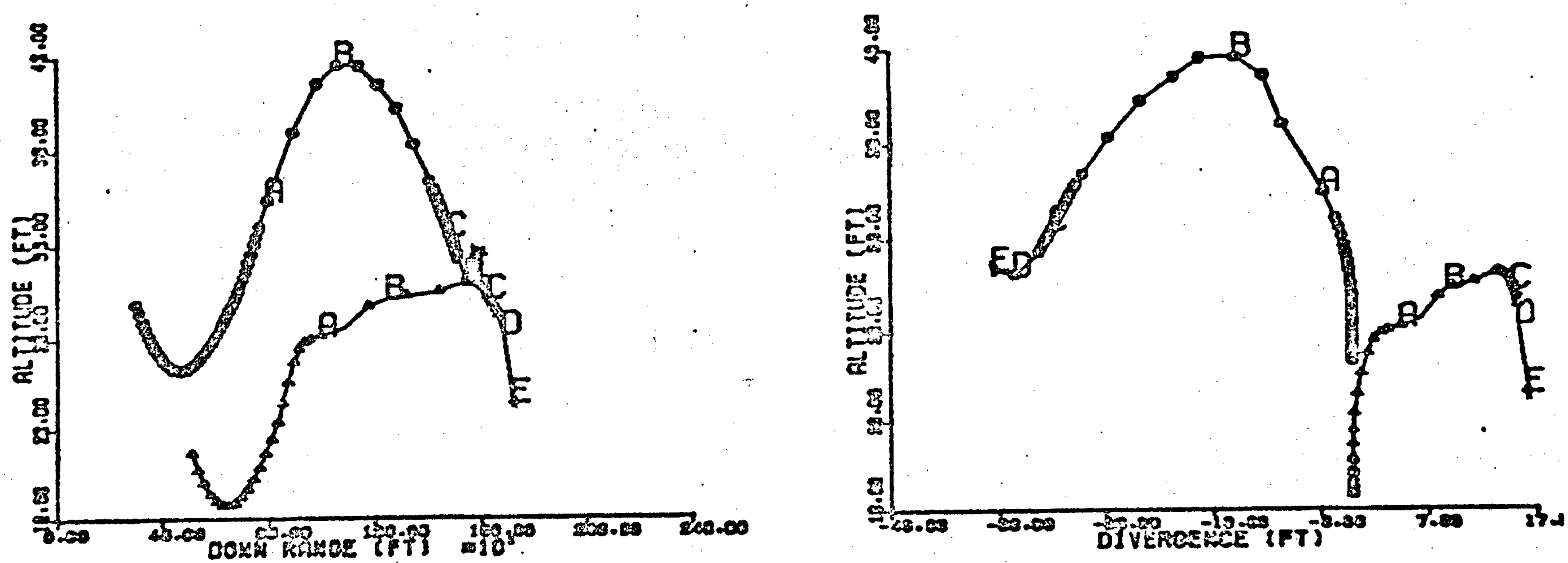


Figure D-29

TF-18 PERFORMANCE STUDY - TEST 1.15 .2 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 600 KNOTS
ALT: 40 FT SINK RATE: 40 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

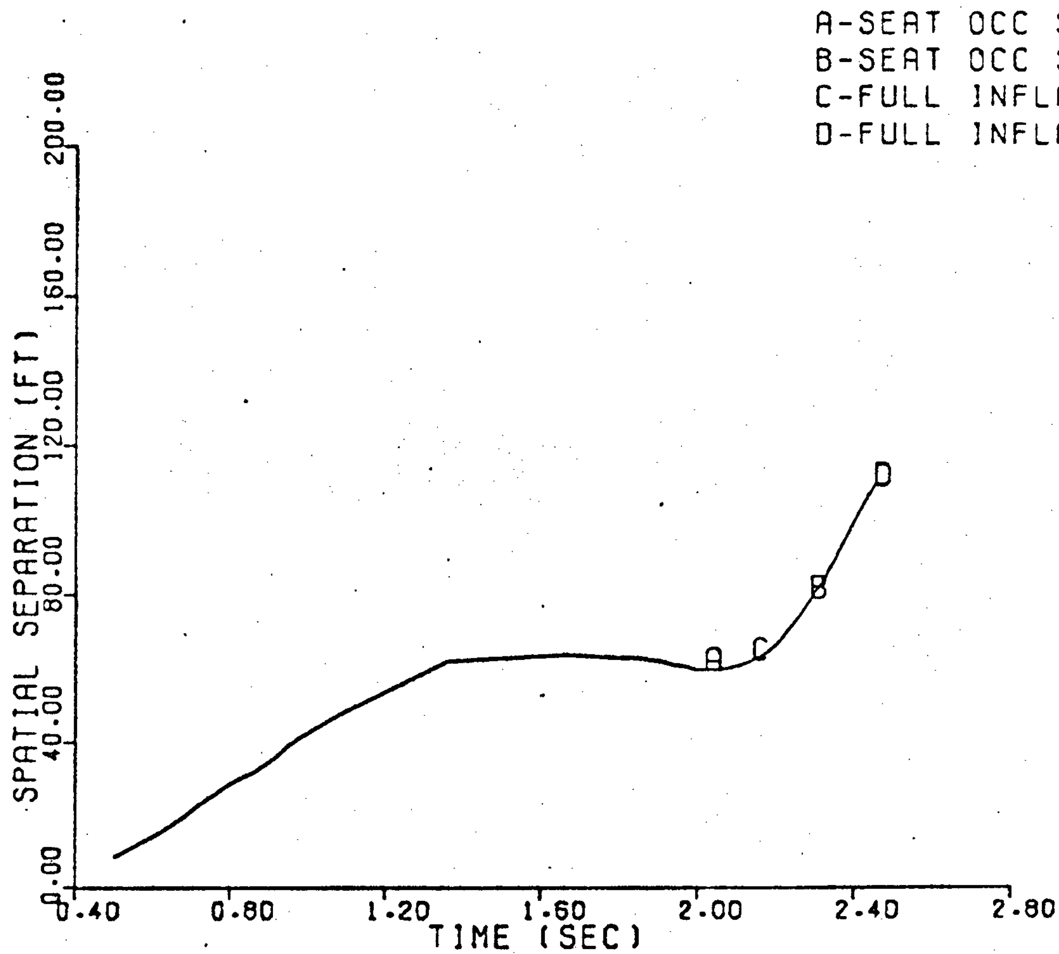


Figure D-30

TF-18 PERFORMANCE STUDY - TEST 1.18 .2 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 100 KNOTS
ALT: 40 FT SINK RATE: 33.33 FT/SEC PITCH: 0 DEG ROLL: 45 DEG

○ REAR SEAT
△ FRONT SEAT

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

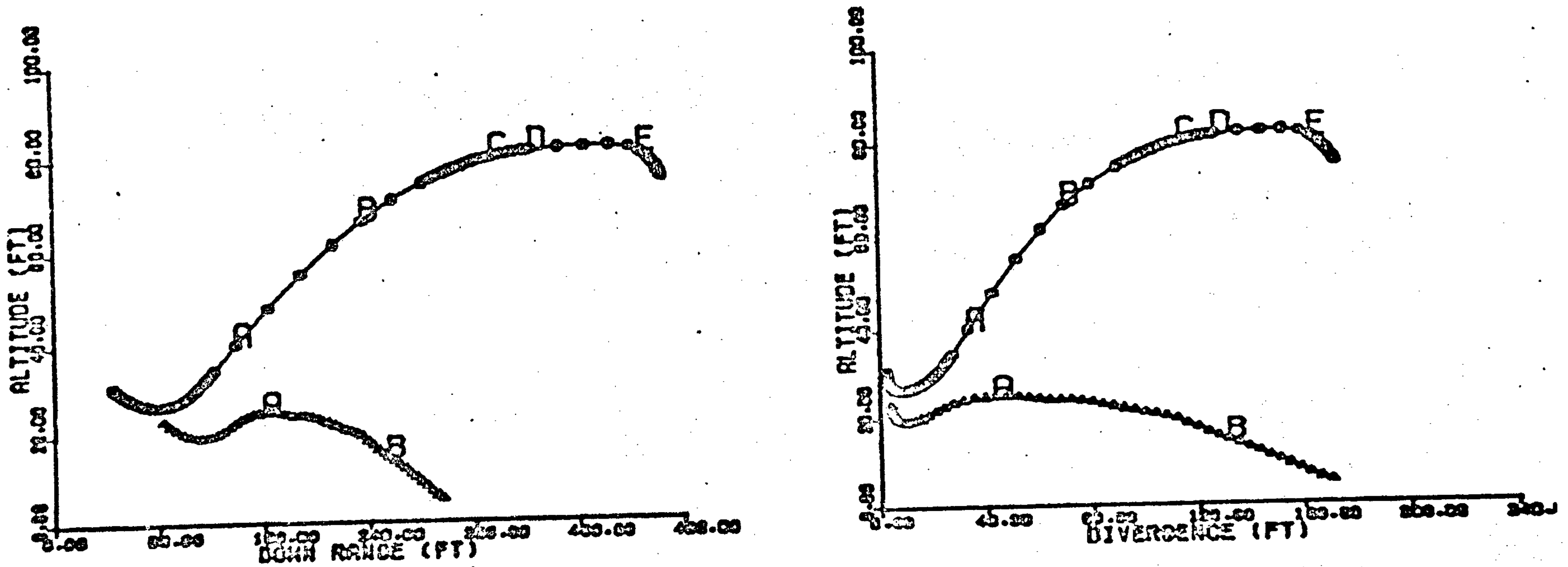


Figure D-31

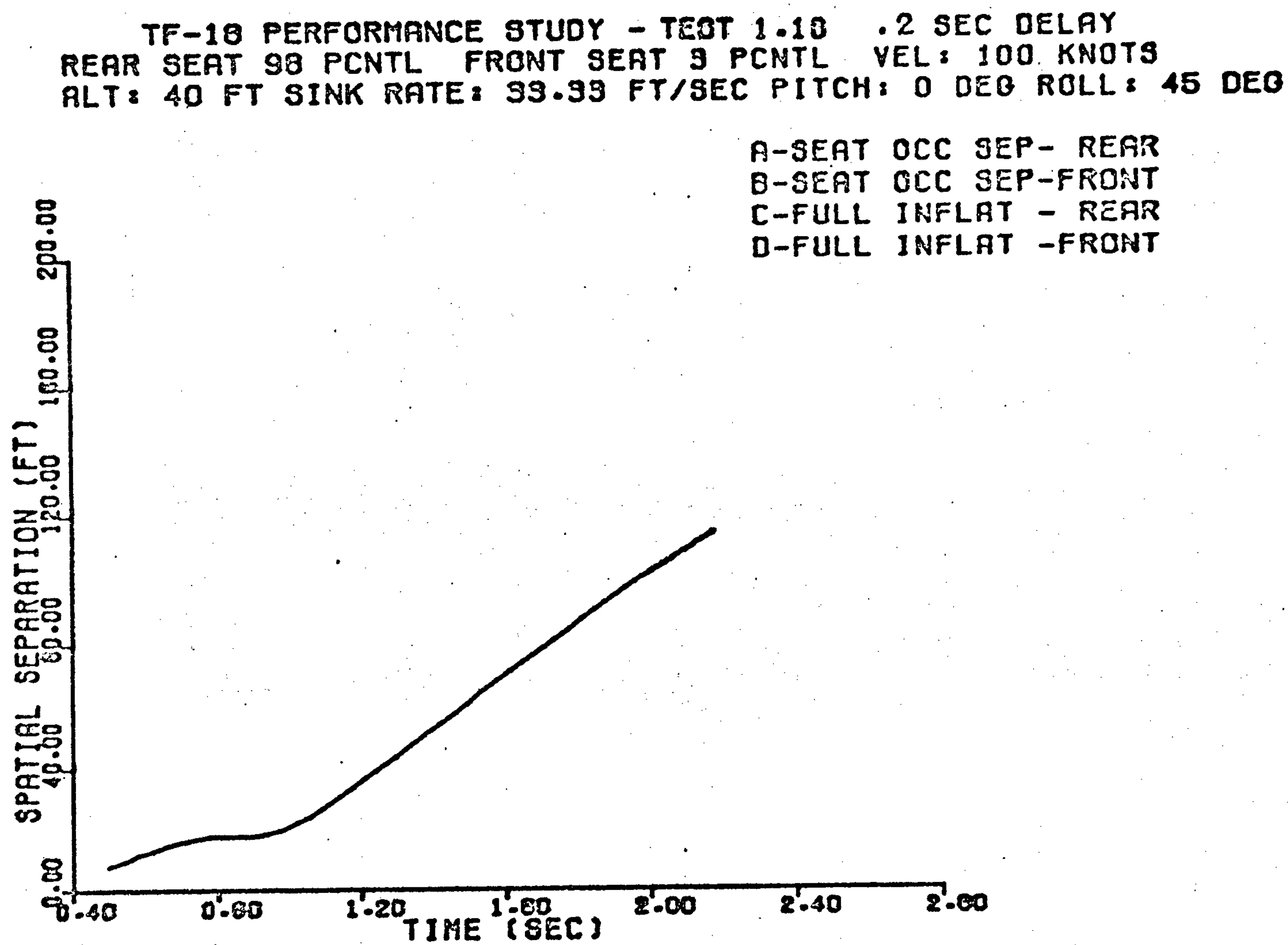
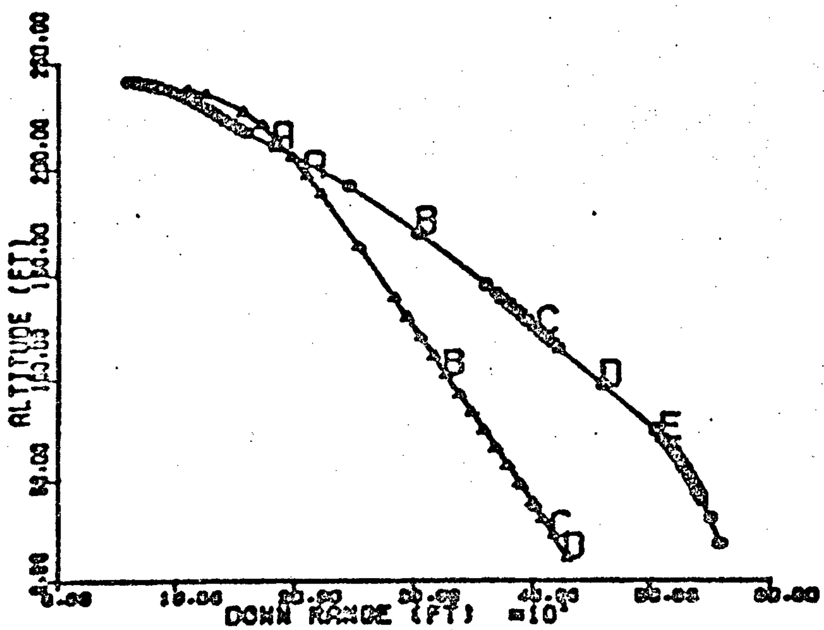

TF-18 PERFORMANCE STUDY - TEST 1.18 .2 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 100 KNOTS
ALT: 40 FT SINK RATE: 33.33 FT/SEC PITCH: 0 DEG ROLL: 45 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
40.00
80.00
120.00
160.00
200.00
TIME (SEC)
0.40
0.80
1.20
1.60
2.00
2.40
2.80

Figure D-32

TF-18 PERFORMANCE STUDY - TEST 1.17 .2 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 130 KNOTS
ALT: 245 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 120 DEG

O REAR SEAT
▲ FRONT SEAT

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION



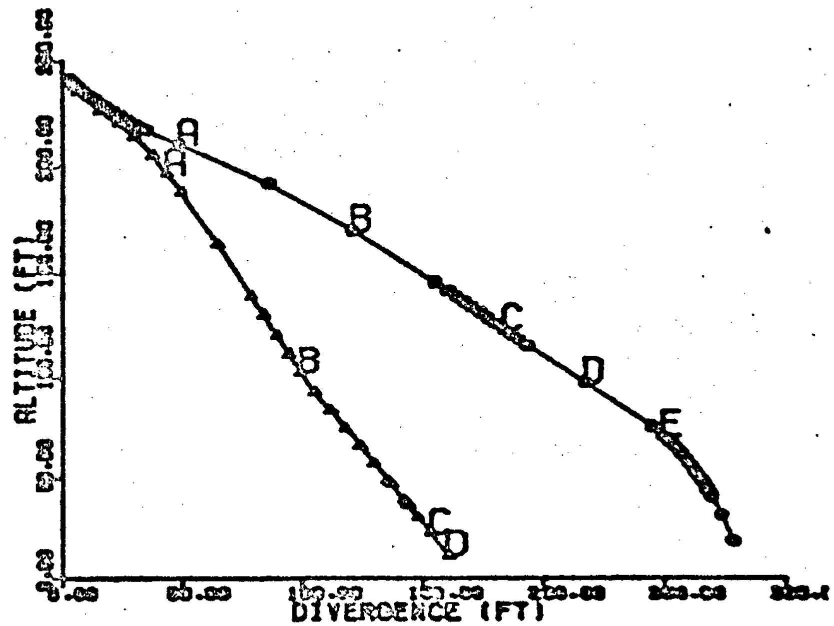


Figure D-33

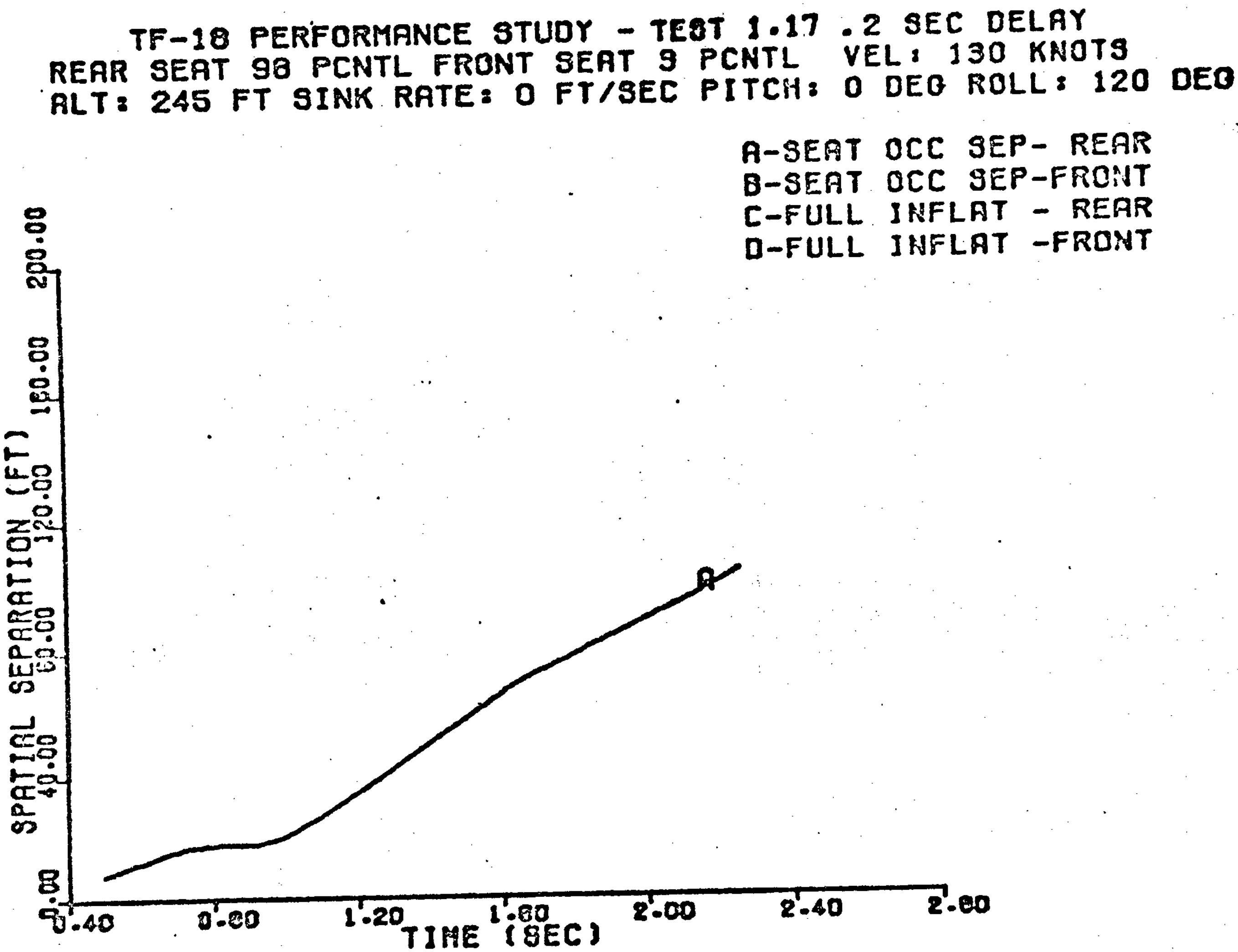

TF-18 PERFORMANCE STUDY - TEST 1.17 .2 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 9 PCNTL VEL: 130 KNOTS
ALT: 245 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 120 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
40.00
80.00
120.00
160.00
200.00
TIME (SEC)
0.40
0.80
1.20
1.60
2.00
2.40
2.80
A

Figure D-34

TF-18 PERFORMANCE STUDY - TEST 1.18 .2 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 130 KNOTS
ALT: 384 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 180 DEG

○ REAR SEAT
△ FRONT SEAT

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

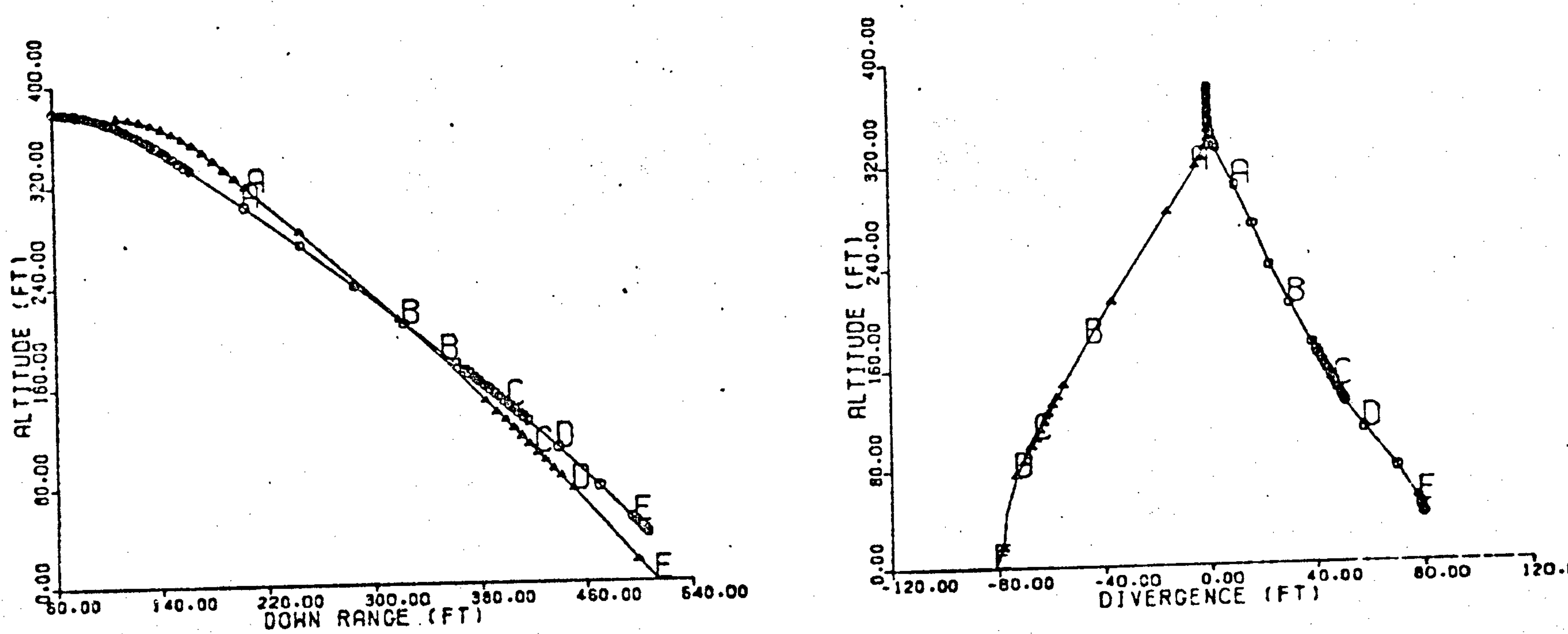


Figure D-35

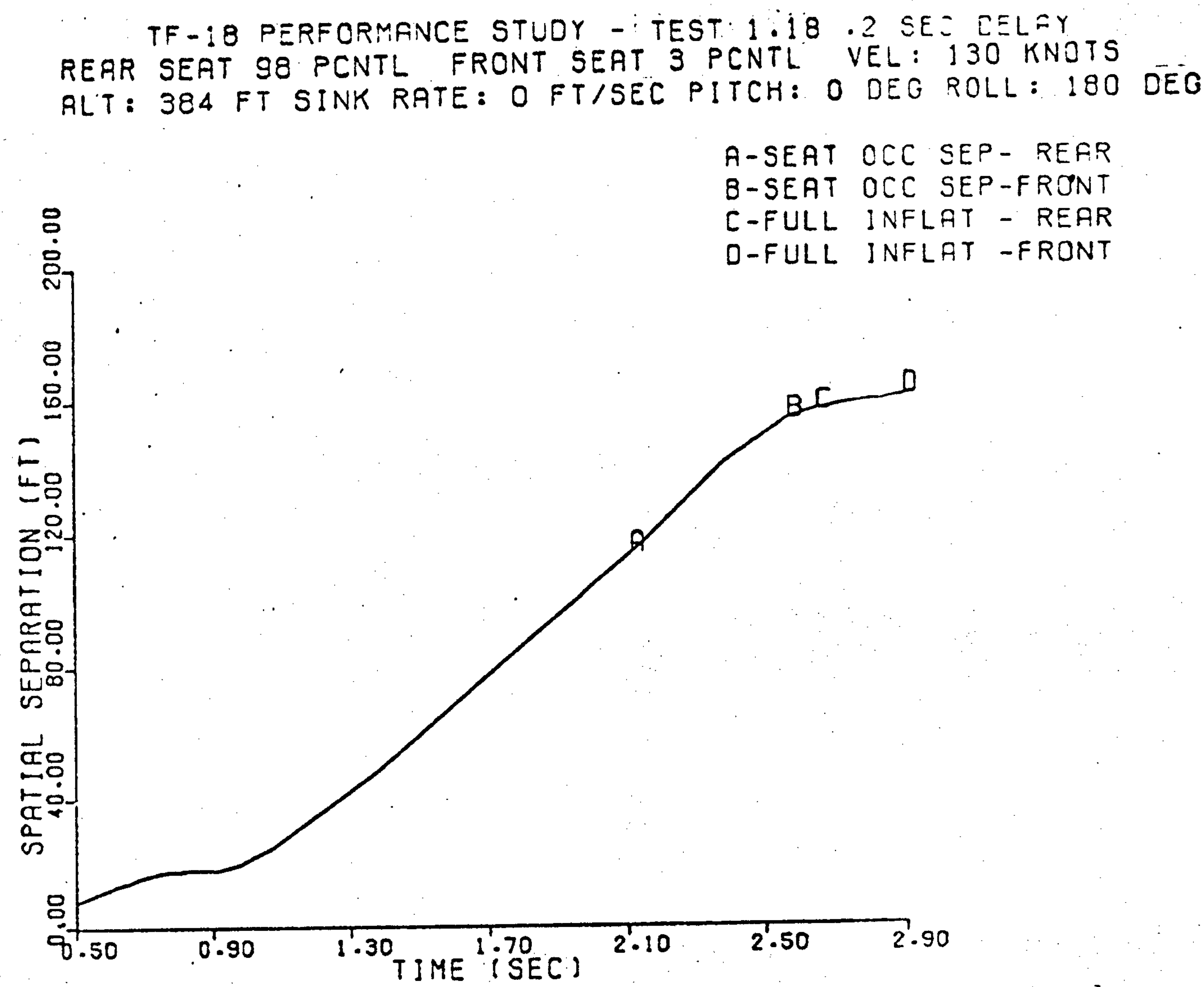

TF-18 PERFORMANCE STUDY - TEST 1.18 .2 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 130 KNOTS
ALT: 384 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 180 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
40.00
80.00
120.00
160.00
200.00
TIME (SEC)
0.50
0.90
1.30
1.70
2.10
2.50
2.90
A
B
C
D

Figure D-36

TF-18 PERFORMANCE STUDY - TEST 1.19 .2 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 130 KNOTS
ALT: 55 FT SINK RATE: 50 FT/SEC PITCH: -15 DEG ROLL: 0 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

○ REAR SEAT
△ FRONT SEAT

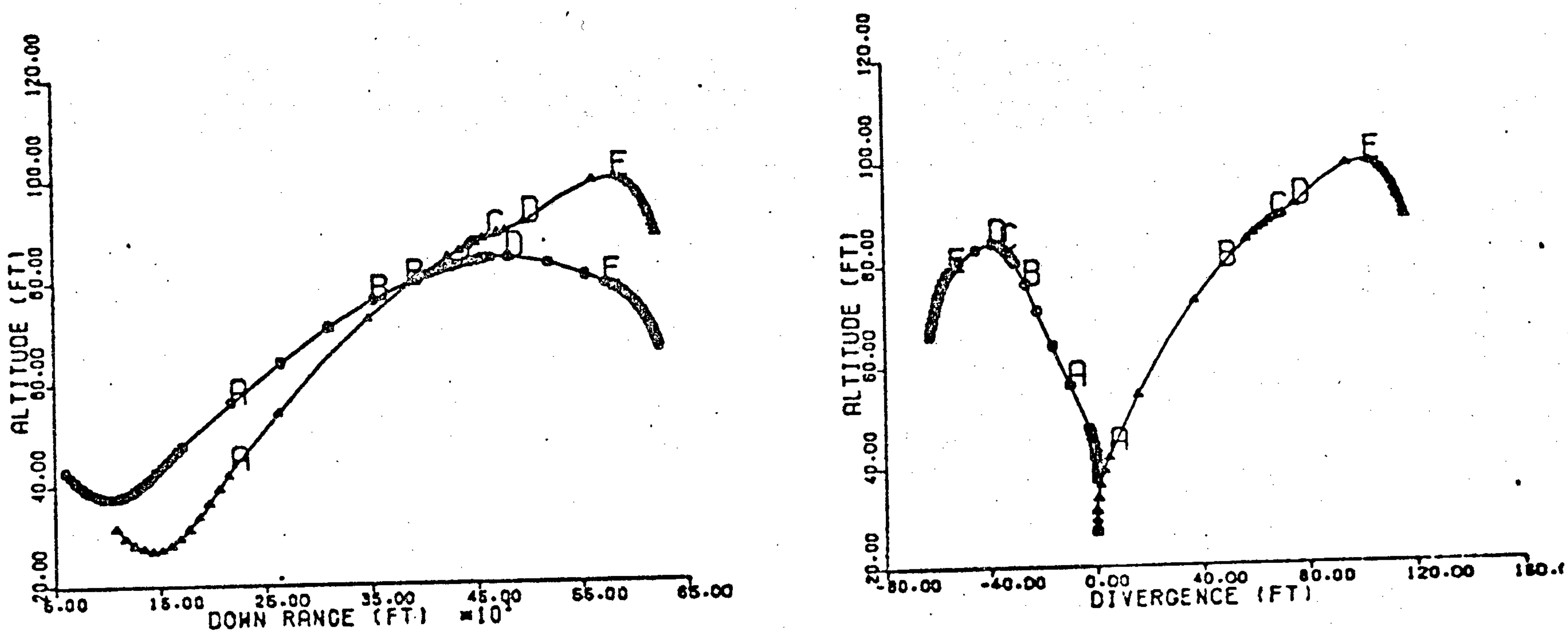


Figure D-37

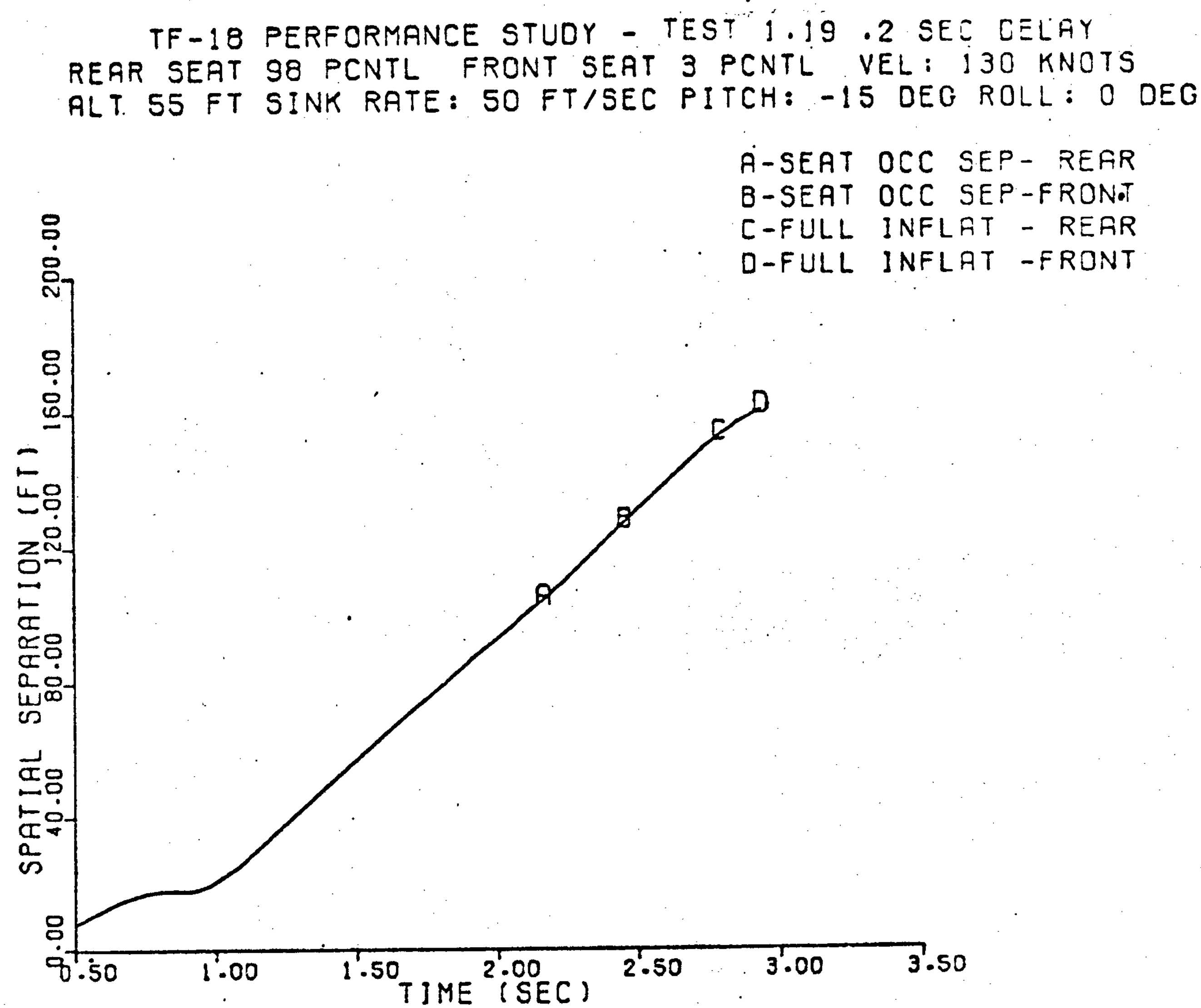
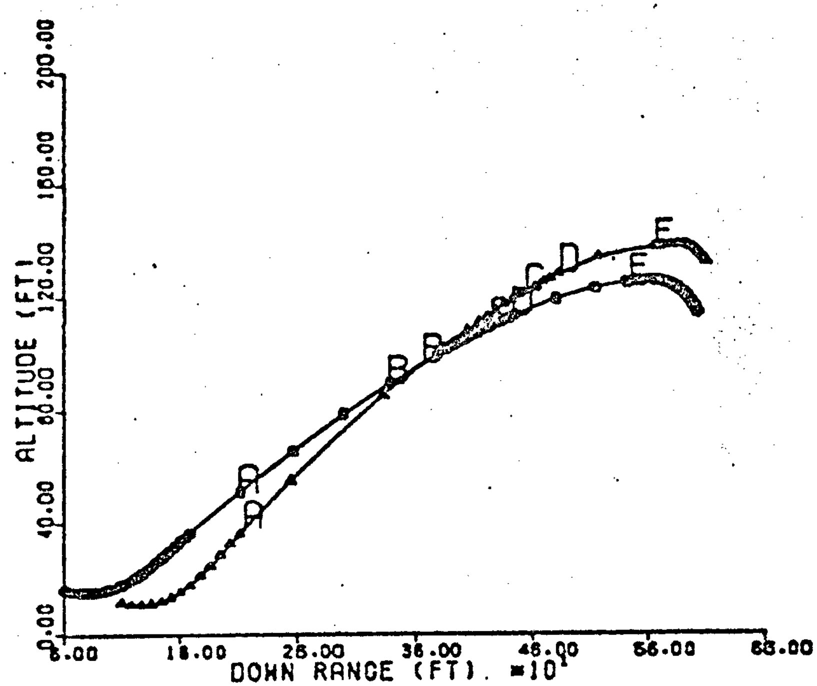

TF-18 PERFORMANCE STUDY - TEST 1.19 .2 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 130 KNOTS
ALT 55 FT SINK RATE: 50 FT/SEC PITCH: -15 DEG ROLL: 0 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
40.00
80.00
120.00
160.00
200.00
TIME (SEC)
0.50
1.00
1.50
2.00
2.50
3.00
3.50
A
B
C
D

Figure D-38

TF-18 PERFORMANCE STUDY - TEST 1.20 .2 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 130 KNOTS
ALT:20 FT SINK RATE: 20 FT/SEC PITCH:-5 DEG ROLL: 0 DEG

○ REAR SEAT
△ FRONT SEAT

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION



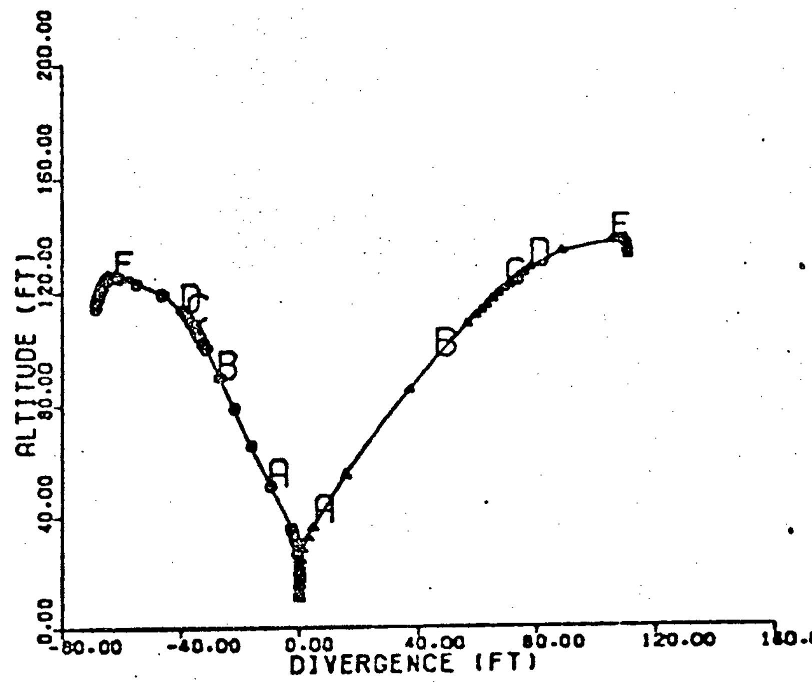


Figure D-39

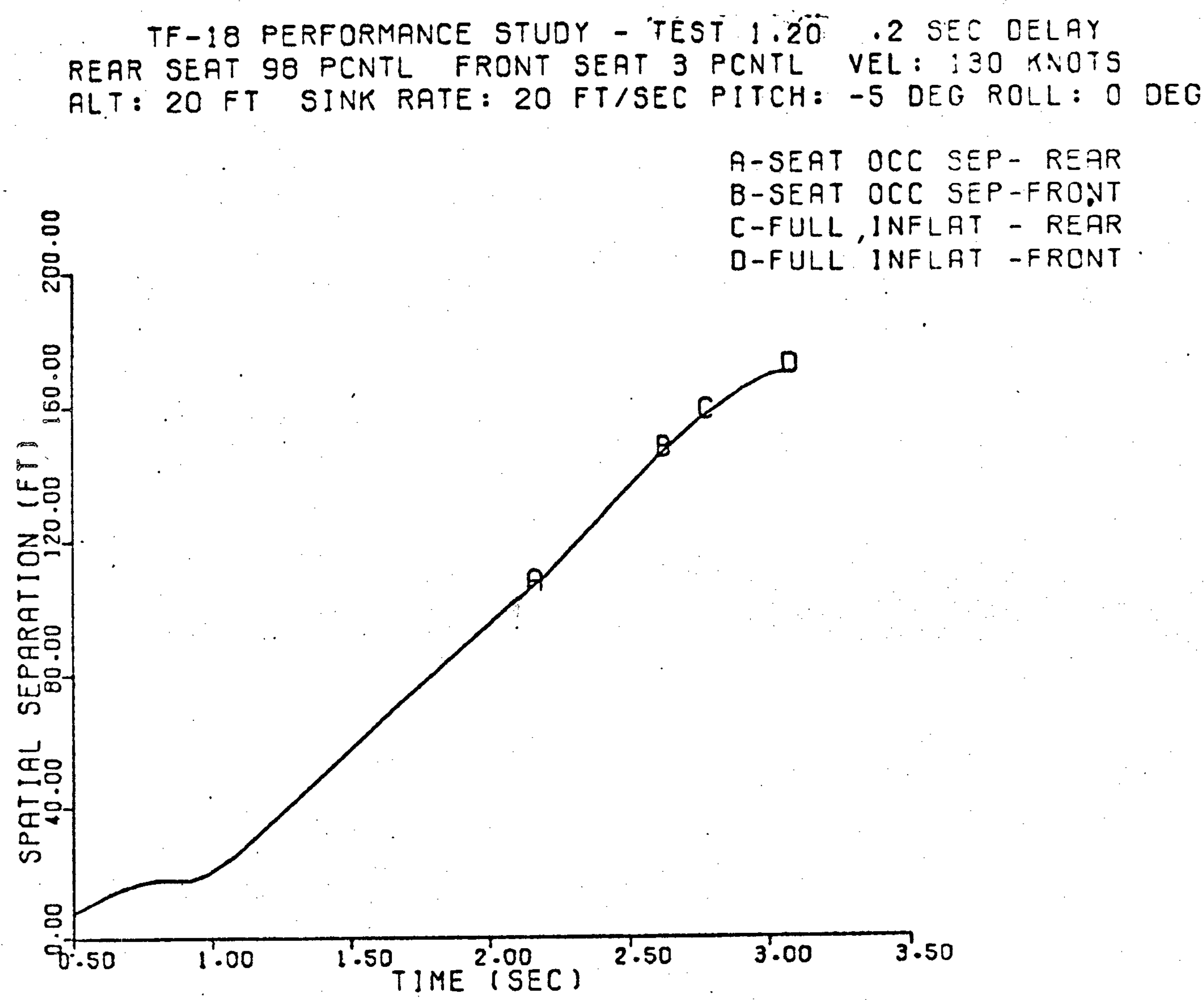

TF-18 PERFORMANCE STUDY - TEST 1.20 .2 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 130 KNOTS
ALT: 20 FT SINK RATE: 20 FT/SEC PITCH: -5 DEG ROLL: 0 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
40.00
80.00
120.00
160.00
200.00
TIME (SEC)
0.50
1.00
1.50
2.00
2.50
3.00
3.50
A
B
C
D

Figure D-40

TF-18 PERFORMANCE STUDY - TEST 1.21 .4 SEC DELAY
REAR SEAT 3 PCNTL FRONT SEAT 98 PCNTL VEL: 0 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

○ REAR SEAT
△ FRONT SEAT

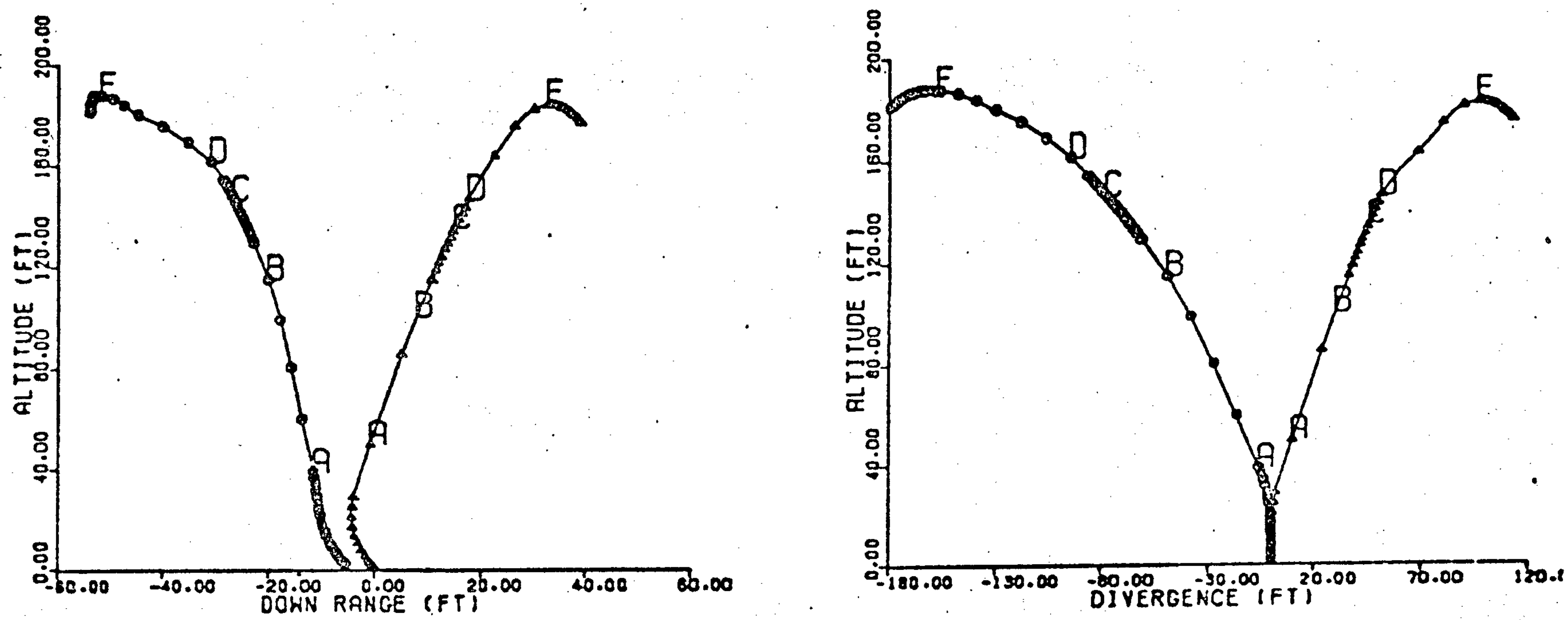


Figure D-41

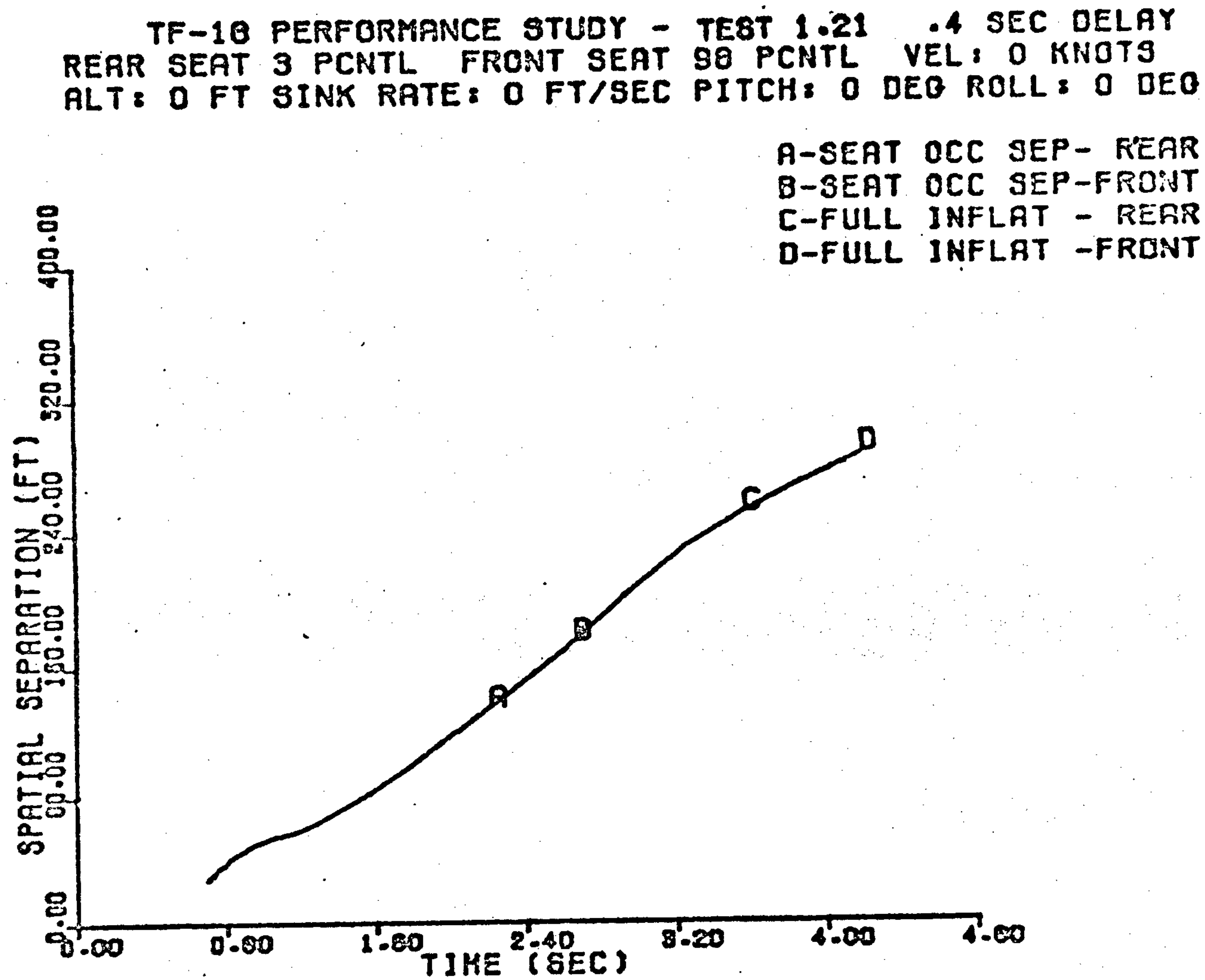

TF-18 PERFORMANCE STUDY - TEST 1.21 .4 SEC DELAY
REAR SEAT 3 PCNTL FRONT SEAT 98 PCNTL VEL: 0 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
80.00
160.00
240.00
320.00
400.00
TIME (SEC)
0.00
0.80
1.60
2.40
3.20
4.00
4.80
A
B
C
D

Figure D-42

TF-18 PERFORMANCE STUDY - TEST 1.22 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 98 PCNTL VEL: 0 KNOTS
ALT: 0 KNOTS SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

○ REAR SEAT
△ FRONT SEAT

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

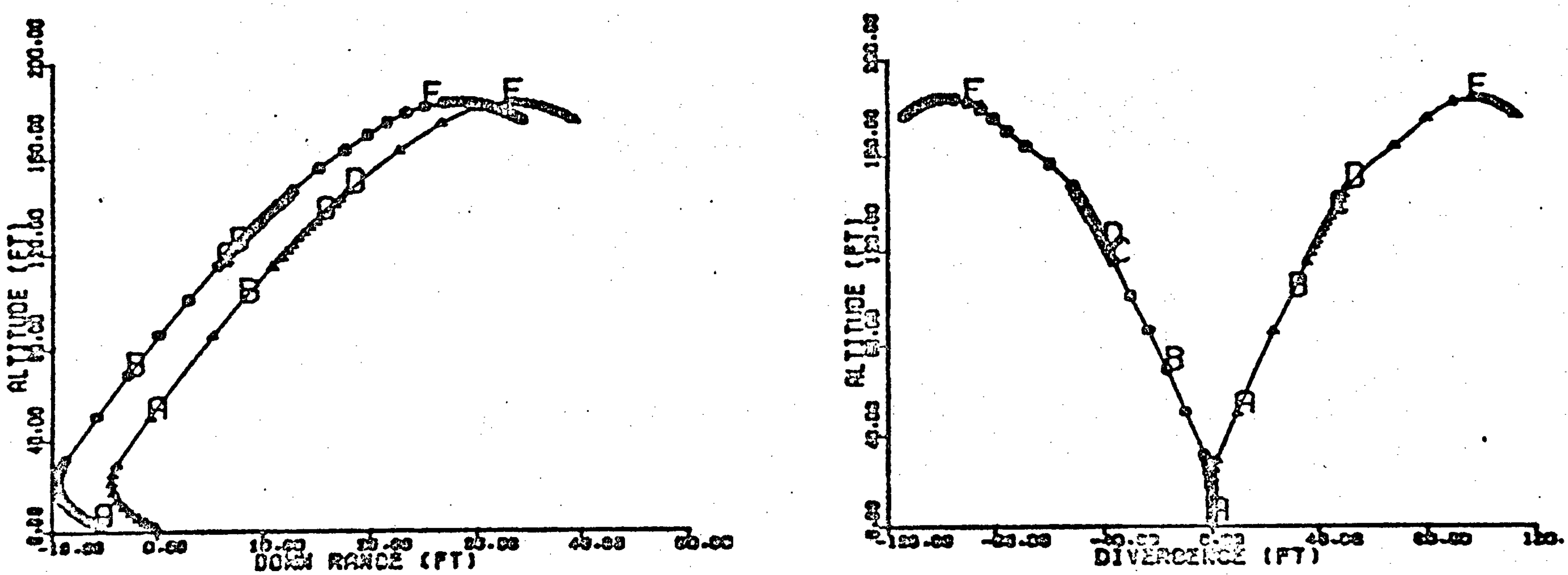


Figure D-43

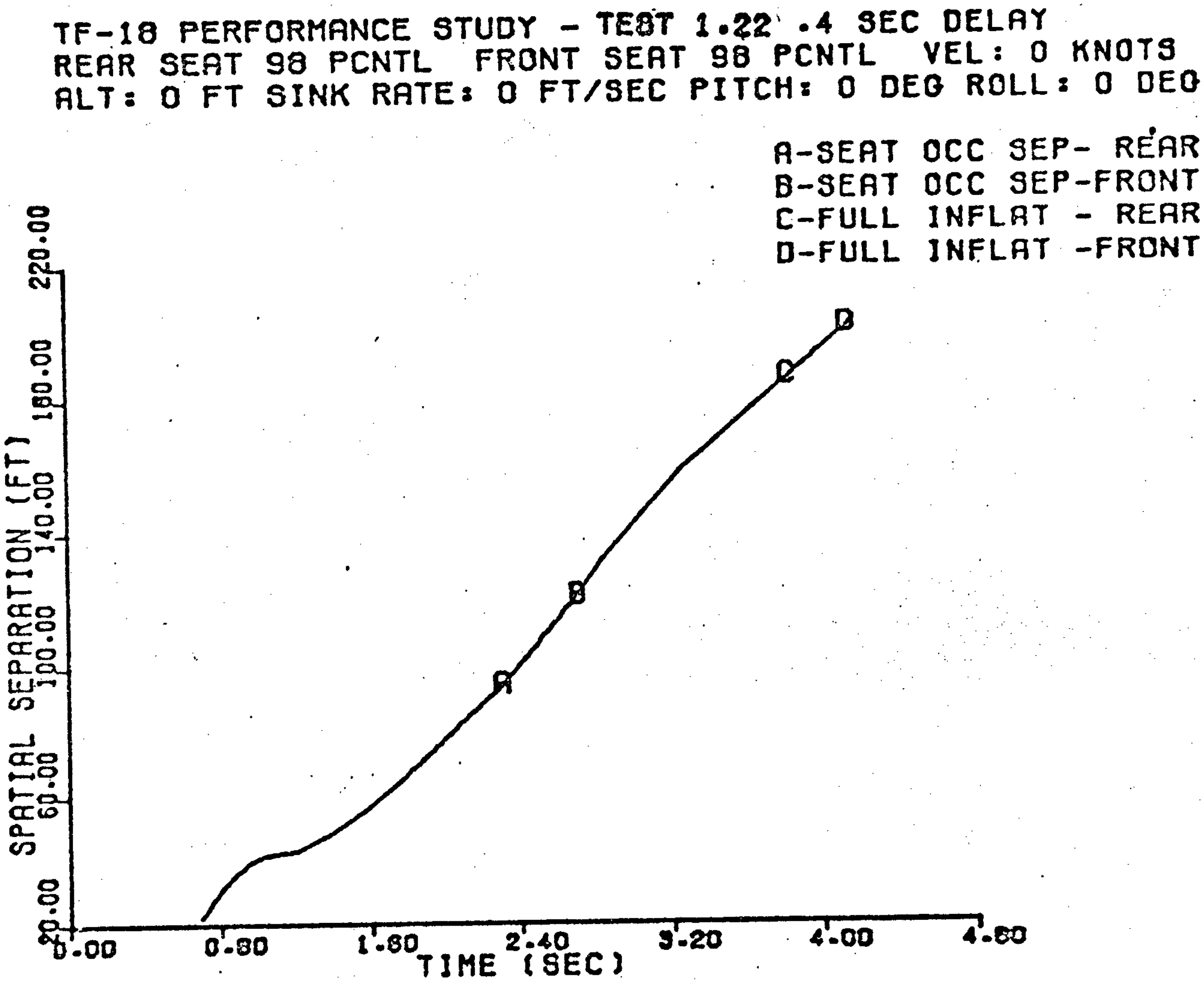
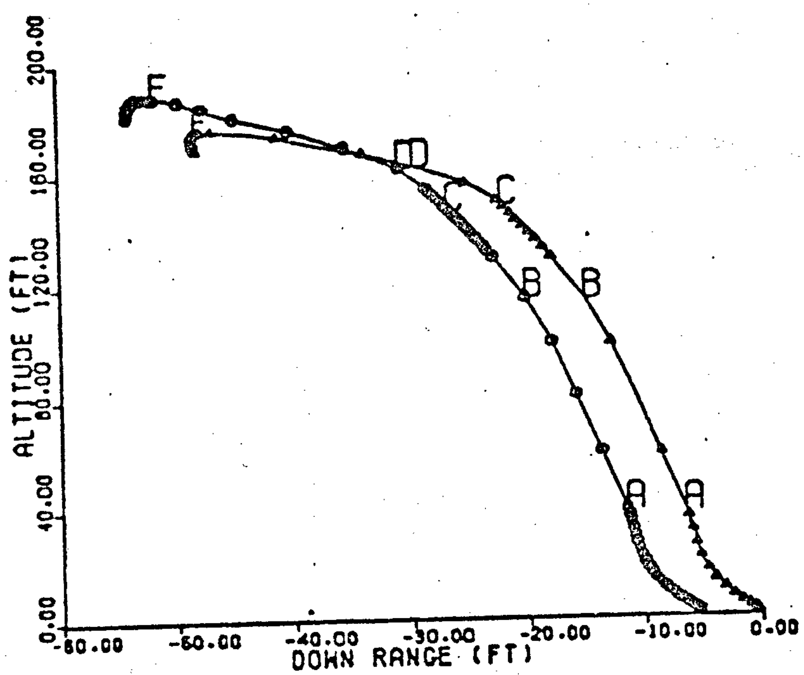

TF-18 PERFORMANCE STUDY - TEST 1.22 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 98 PCNTL VEL: 0 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
20.00
60.00
100.00
140.00
180.00
220.00
0.00
0.80
1.60
2.40
3.20
4.00
4.80
TIME (SEC)
A
B
C
D

Figure D-44

TF-18 PERFORMANCE STUDY - TEST 1.23 .4 SEC DELAY
REAR SEAT 3 PCNTL FRONT SEAT 3 PCNTL VEL: 0 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

O REAR SEAT
Δ FRONT SEAT

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION



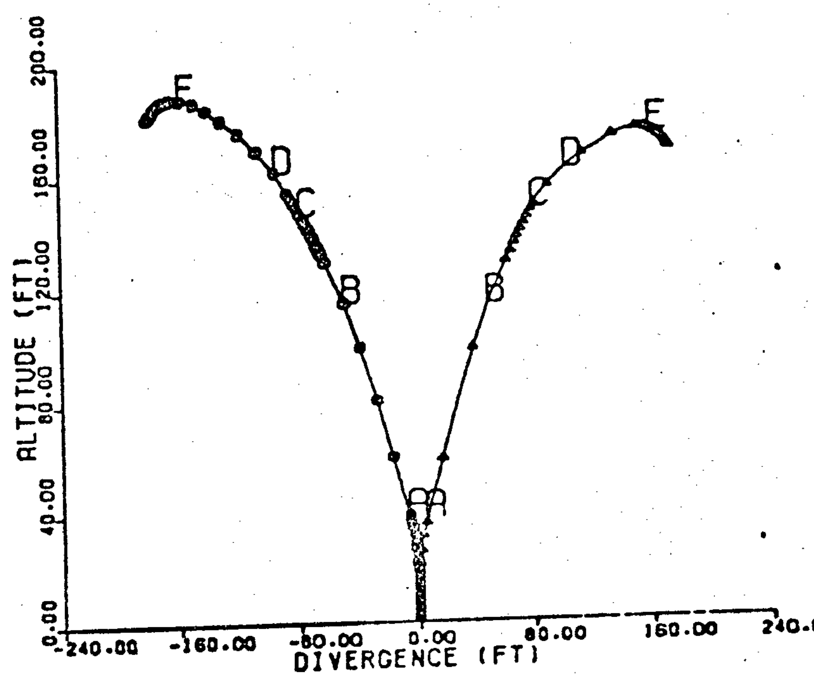


Figure D-45

TF-18 PERFORMANCE STUDY - TEST 1.23 .4 SEC DELAY
REAR SEAT 3 PCNTL FRONT SEAT 3 PCNTL VEL: 0 KNOTS
ALT: 0 FT SINK RATE: 0 FT/ SEC PITCH: 0 DEG ROLL: 0 DEG

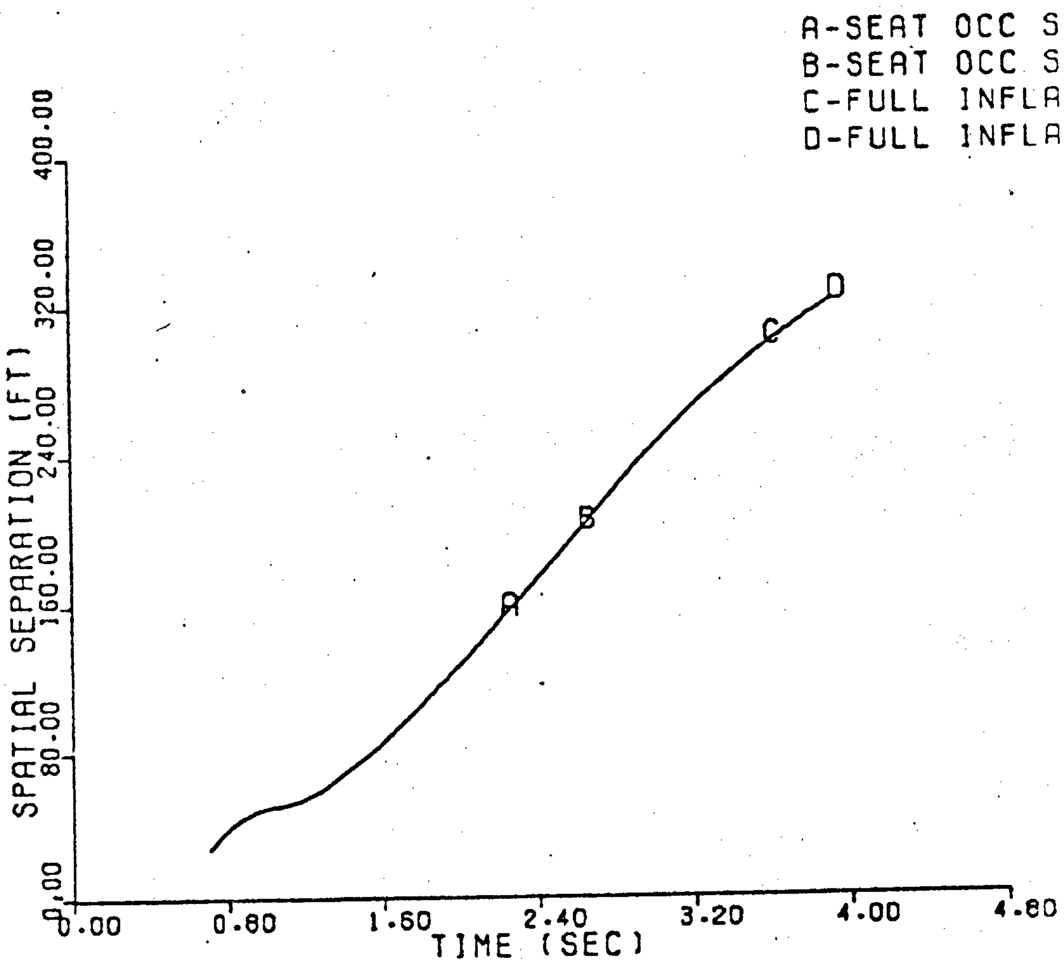


Figure D-46

TF-18 PERFORMANCE STUDY - TEST 1.24 .4 SEC DELAY
REAR SEAT 3 PCNTL FRONT SEAT 98 PCNTL VEL: 200 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

⊙ REAR SEAT
△ FRONT SEAT

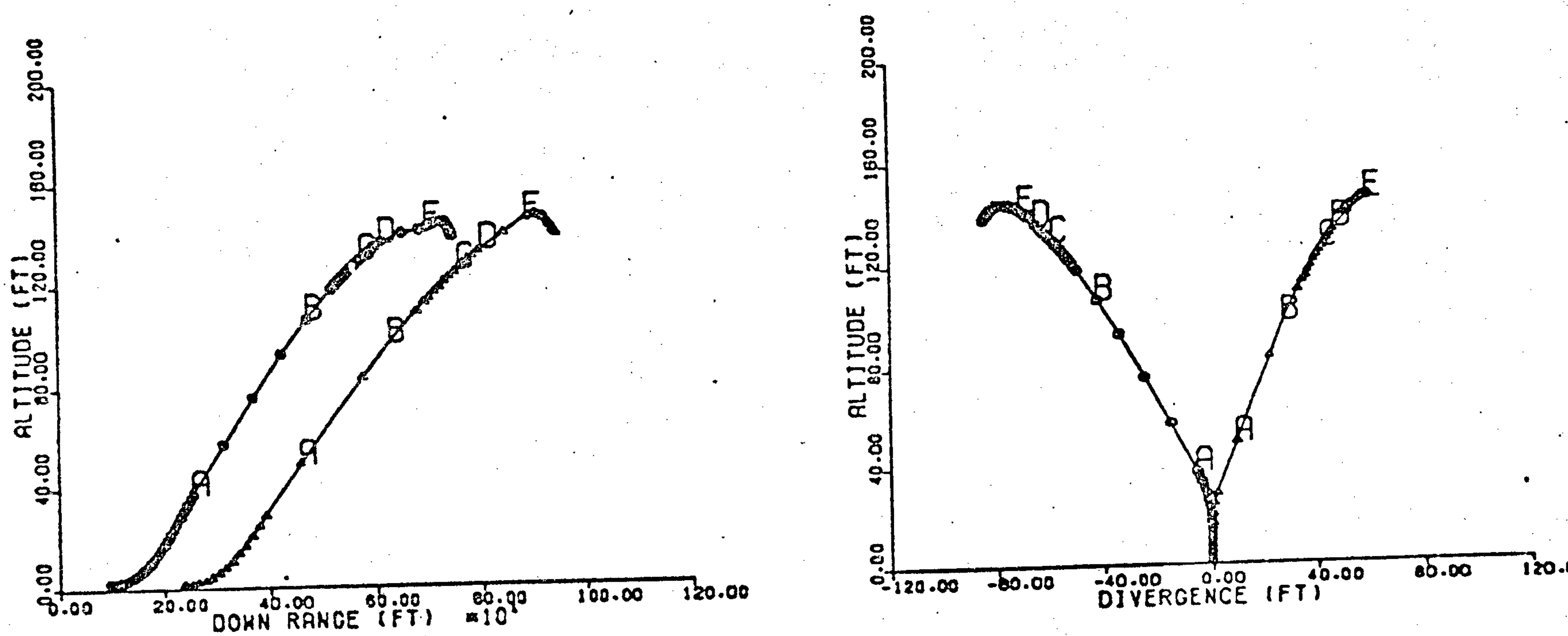


Figure D-47

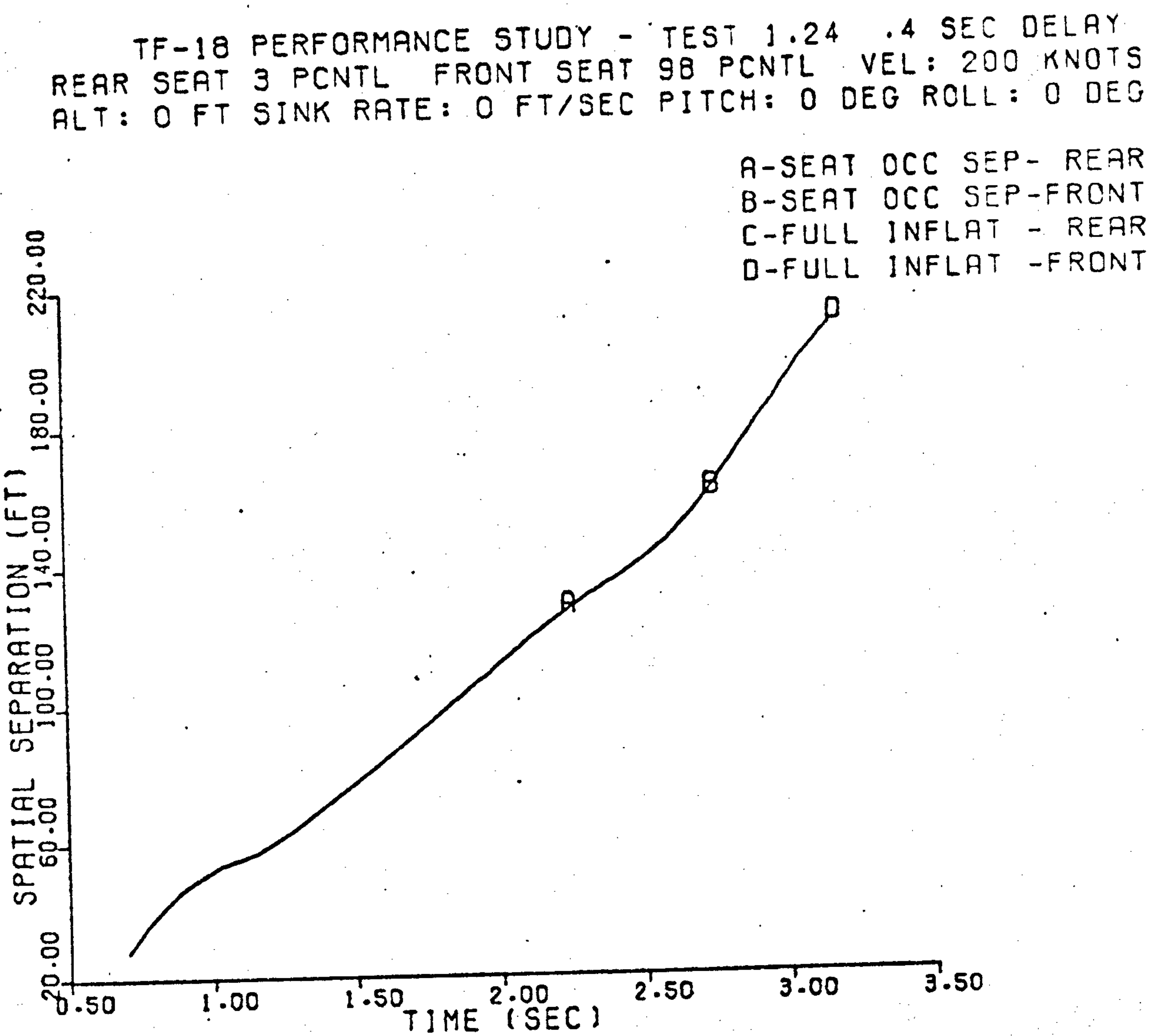

TF-18 PERFORMANCE STUDY - TEST 1.24 .4 SEC DELAY
REAR SEAT 3 PCNTL FRONT SEAT 98 PCNTL VEL: 200 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
20.00
60.00
100.00
140.00
180.00
220.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
TIME (SEC)
A
B
D

Figure D-48

TF-18 PERFORMANCE STUDY - TEST 1.25 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 98 PCNTL VEL: 200 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

⊙ REAR SEAT
△ FRONT SEAT

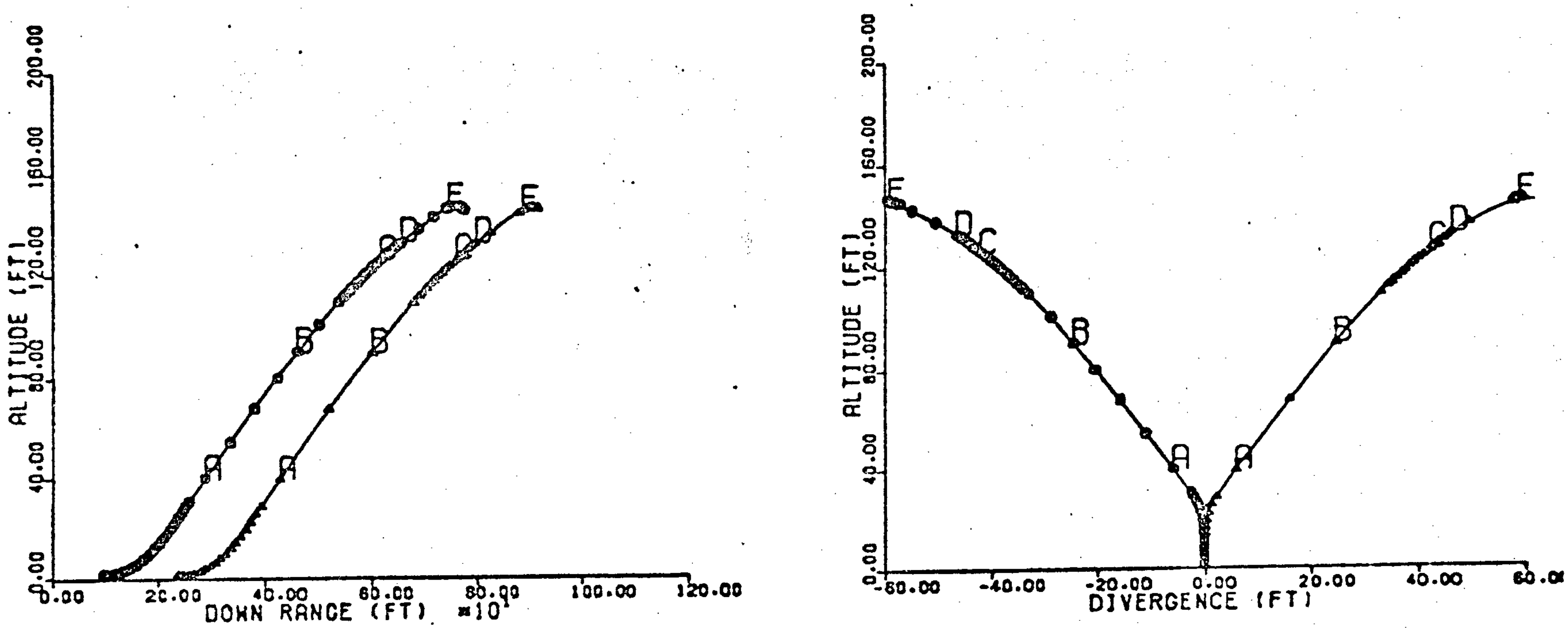


Figure D-49

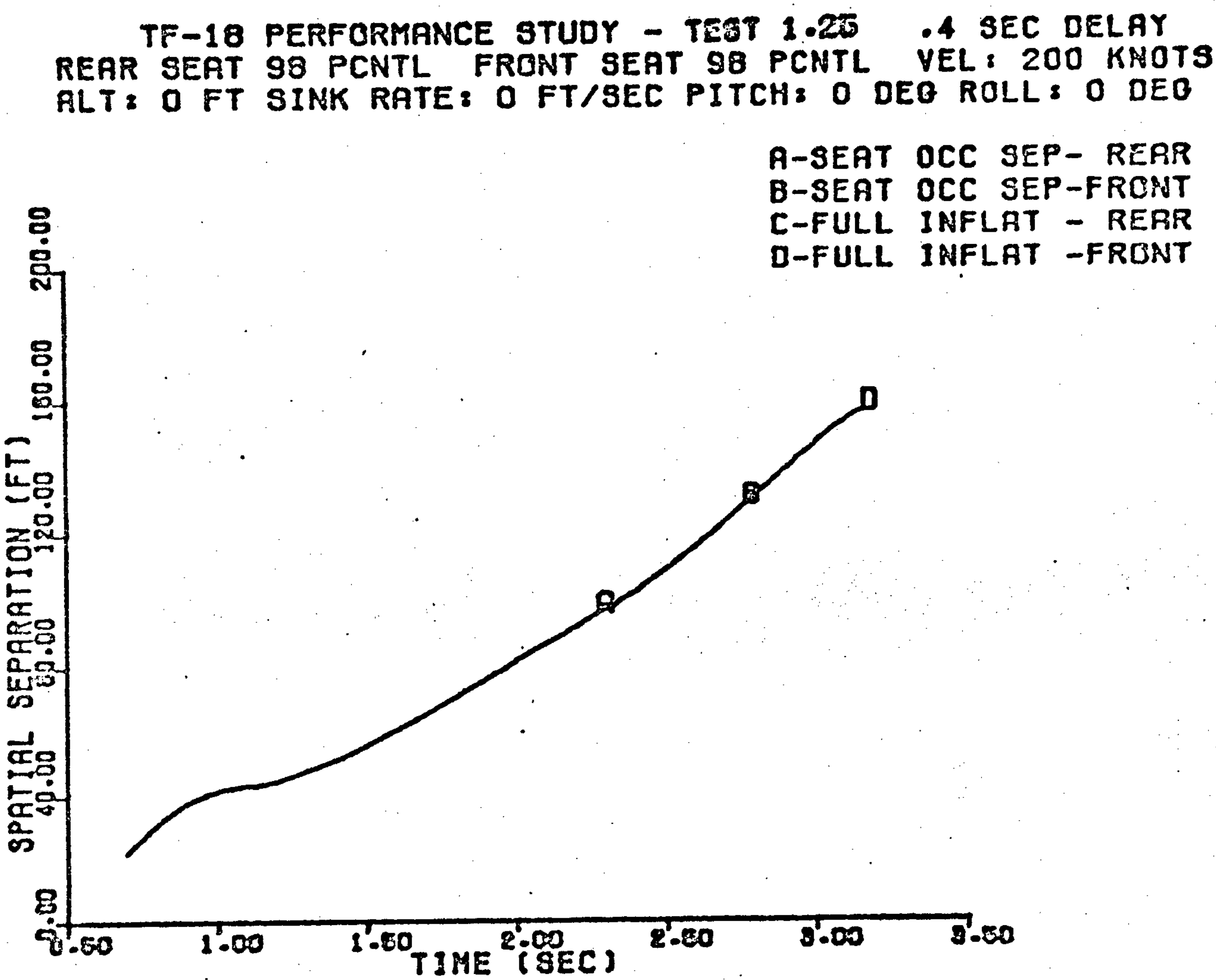

TF-18 PERFORMANCE STUDY - TEST 1.25 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 98 PCNTL VEL: 200 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
40.00
80.00
120.00
160.00
200.00
TIME (SEC)
0.50
1.00
1.50
2.00
2.50
3.00
3.50
A
B
D

Figure D-50

TF-18 PERFORMANCE STUDY - TEST 1.26 .4 SEC DELAY
REAR SEAT 3 PCNTL FRONT SEAT 3 PCNTL VEL: 200 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

○ REAR SEAT
△ FRONT SEAT

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

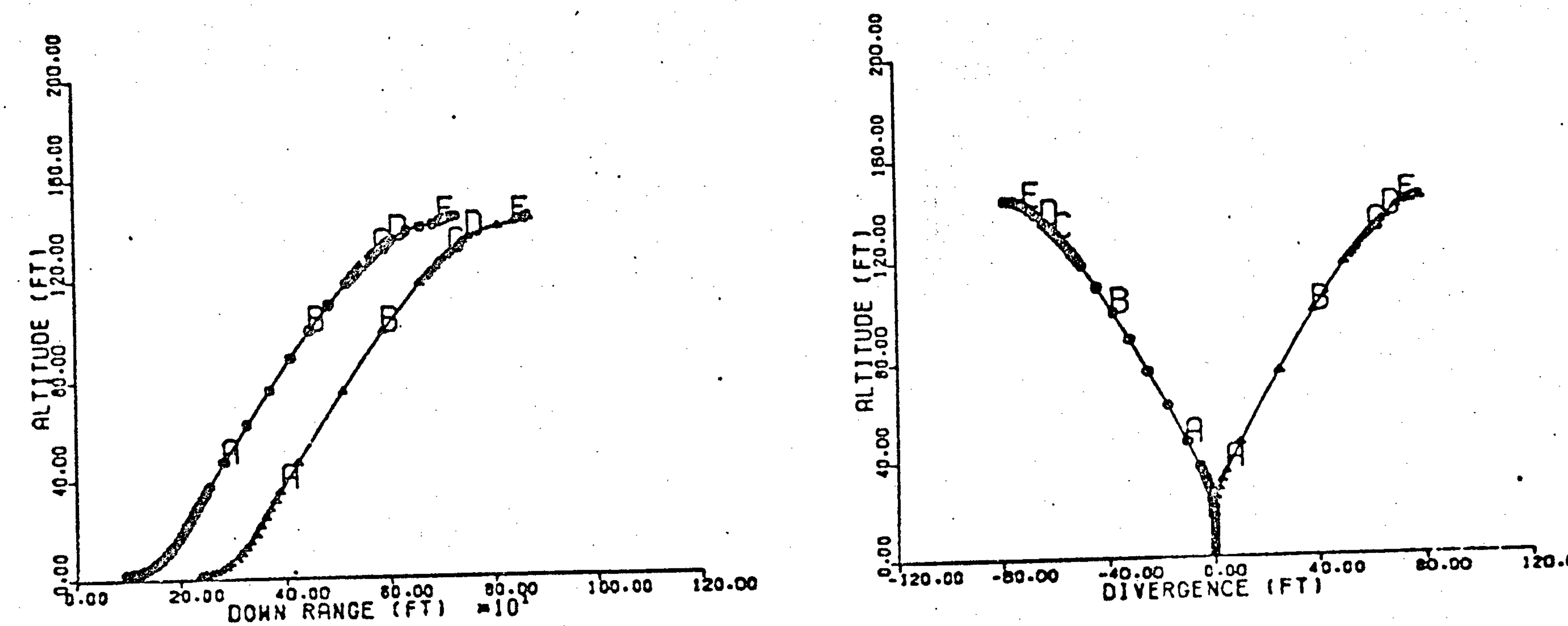


Figure D-51

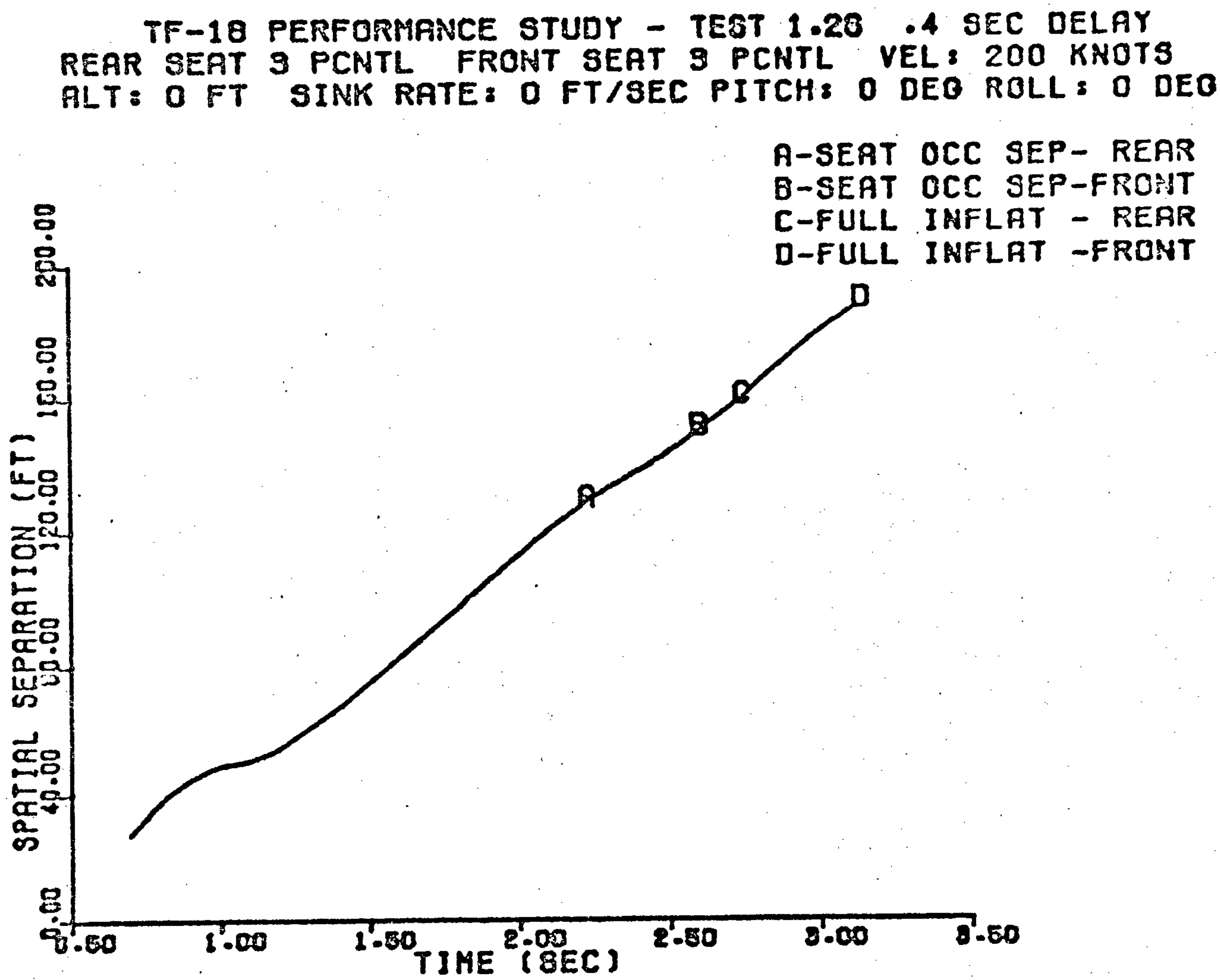
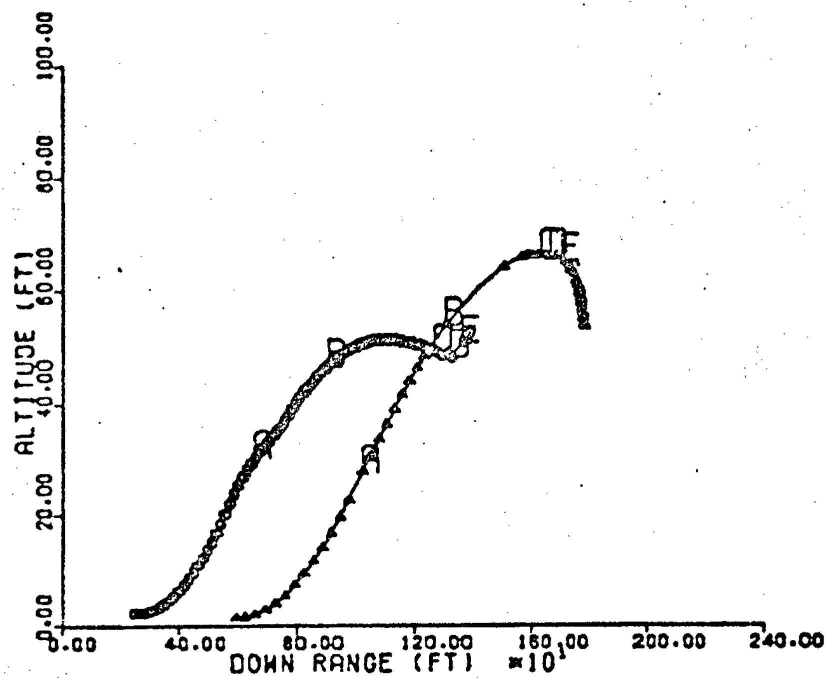

TF-18 PERFORMANCE STUDY - TEST 1.28 .4 SEC DELAY
REAR SEAT 3 PCNTL FRONT SEAT 3 PCNTL VEL: 200 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
40.00
80.00
120.00
160.00
200.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
TIME (SEC)
A
B
C
D

Figure D-52

TF-18 PERFORMANCE STUDY - TEST 1.27 .4 SEC DELAY
REAR SEAT 3 PCNTL FRONT SEAT 98 PCNTL VEL: 500 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

○ REAR SEAT
△ FRONT SEAT

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION



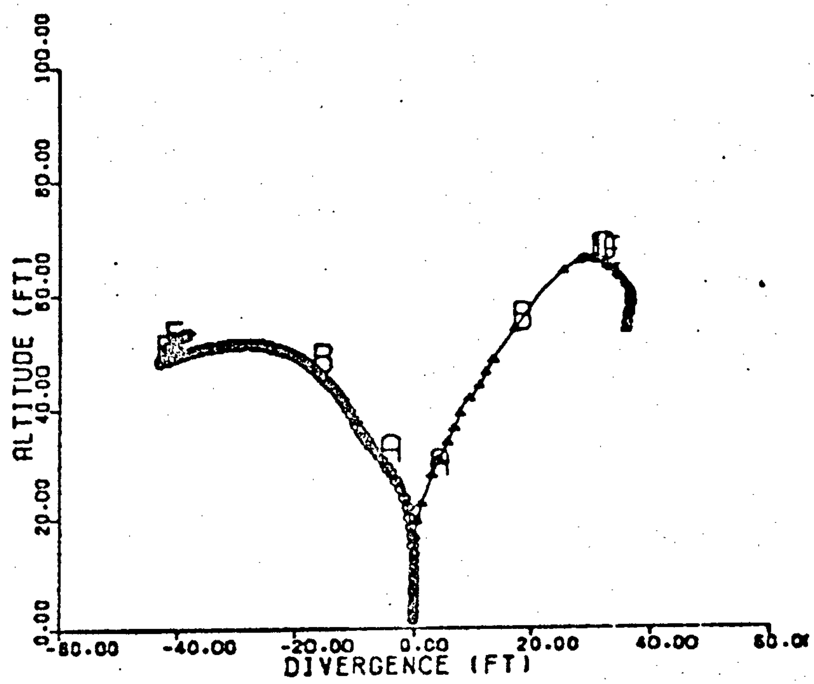


Figure D-53

TF-18 PERFORMANCE STUDY - TEST 1.27 .4 SEC DELAY
REAR SEAT 3 PCNTL FRONT SEAT 98 PCNTL VEL: 500 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

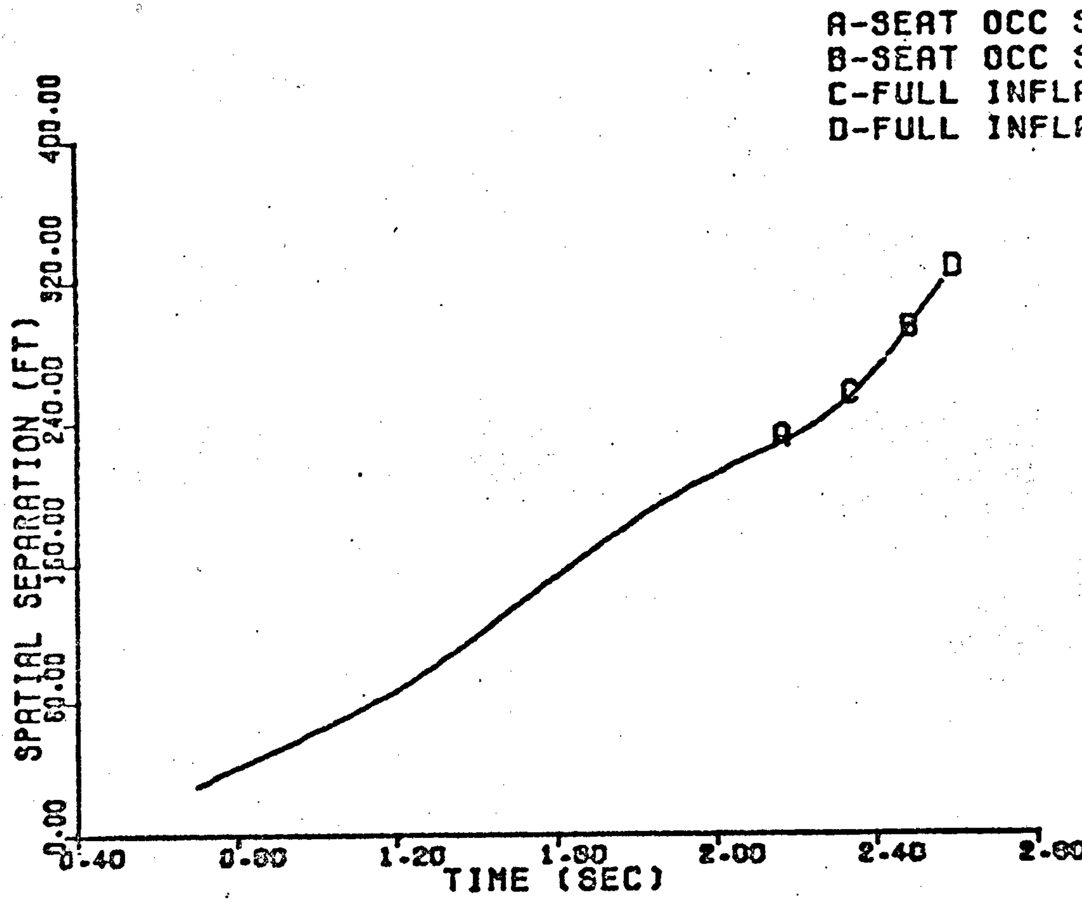


Figure D-54

TF-18 PERFORMANCE STUDY - TEST 1.28 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 98 PCNTL VEL: 500 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

○ REAR SEAT
△ FRONT SEAT

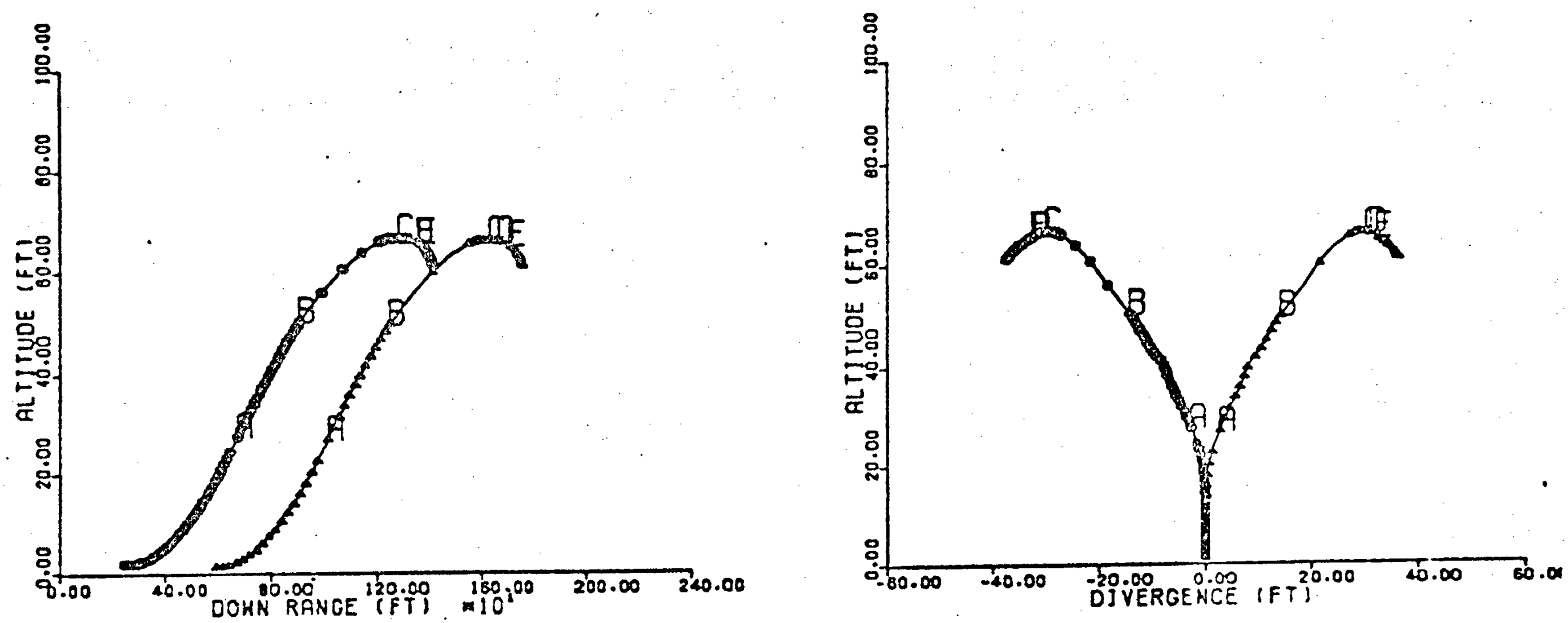


Figure D-55

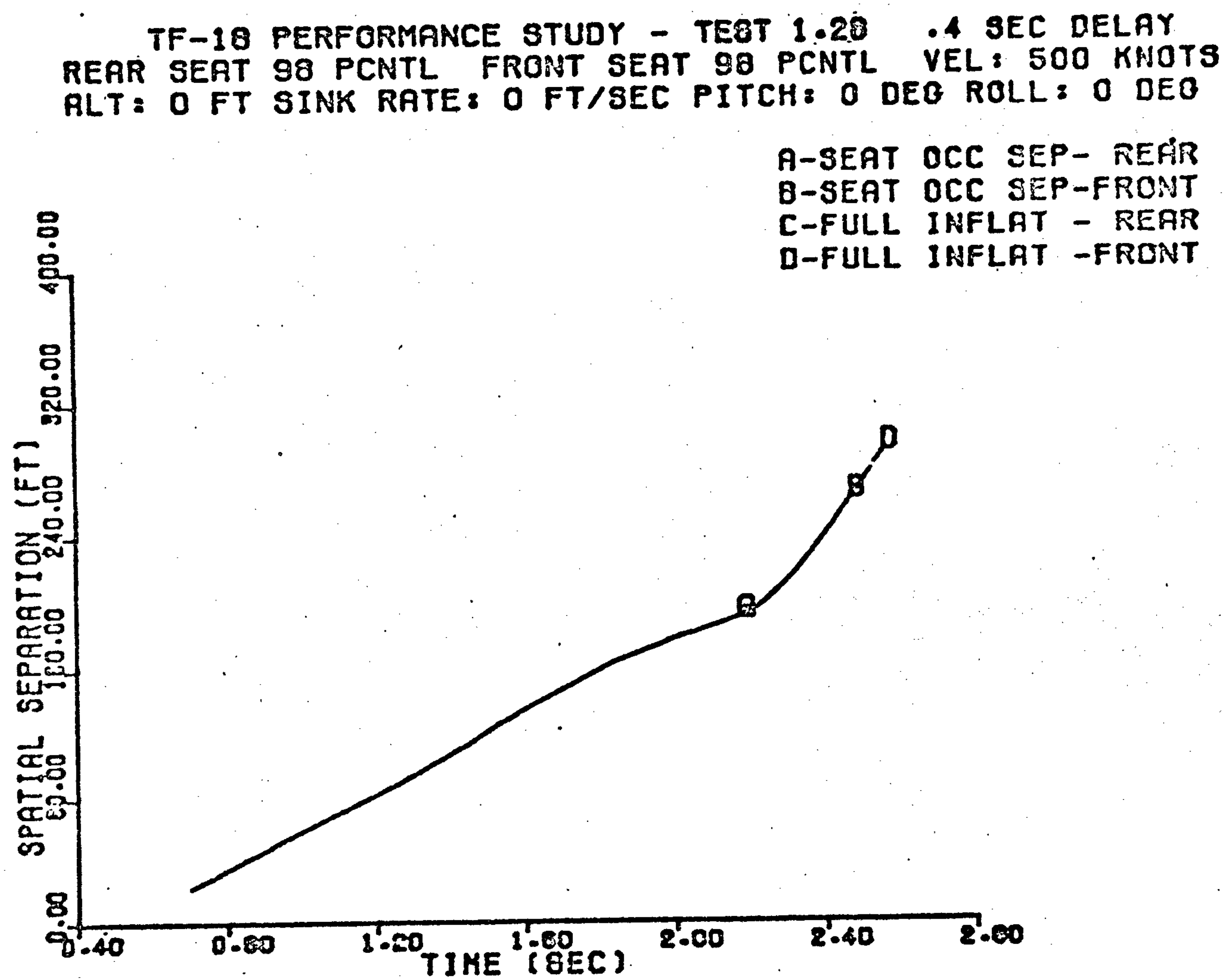
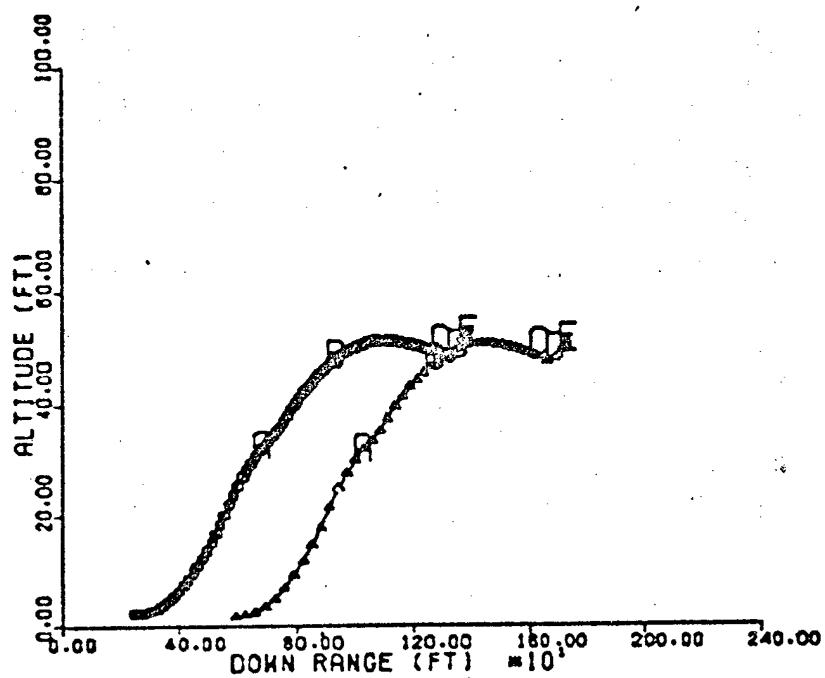

TF-18 PERFORMANCE STUDY - TEST 1.20 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 98 PCNTL VEL: 500 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
80.00
160.00
240.00
320.00
400.00
TIME (SEC)
0.40
0.80
1.20
1.60
2.00
2.40
2.80
B
B
D

Figure D-56

TF-18 PERFORMANCE STUDY - TEST 1.29 .4 SEC DELAY
REAR SEAT 3 PCNTL FRONT SEAT 3 PCNTL VEL: 500 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

○ REAR SEAT
△ FRONT SEAT

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION



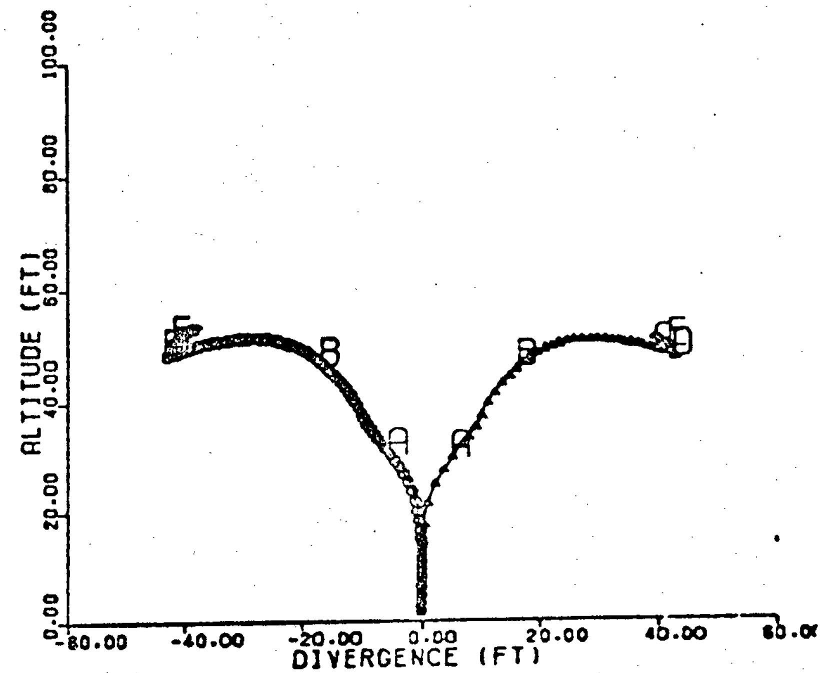


Figure D-57

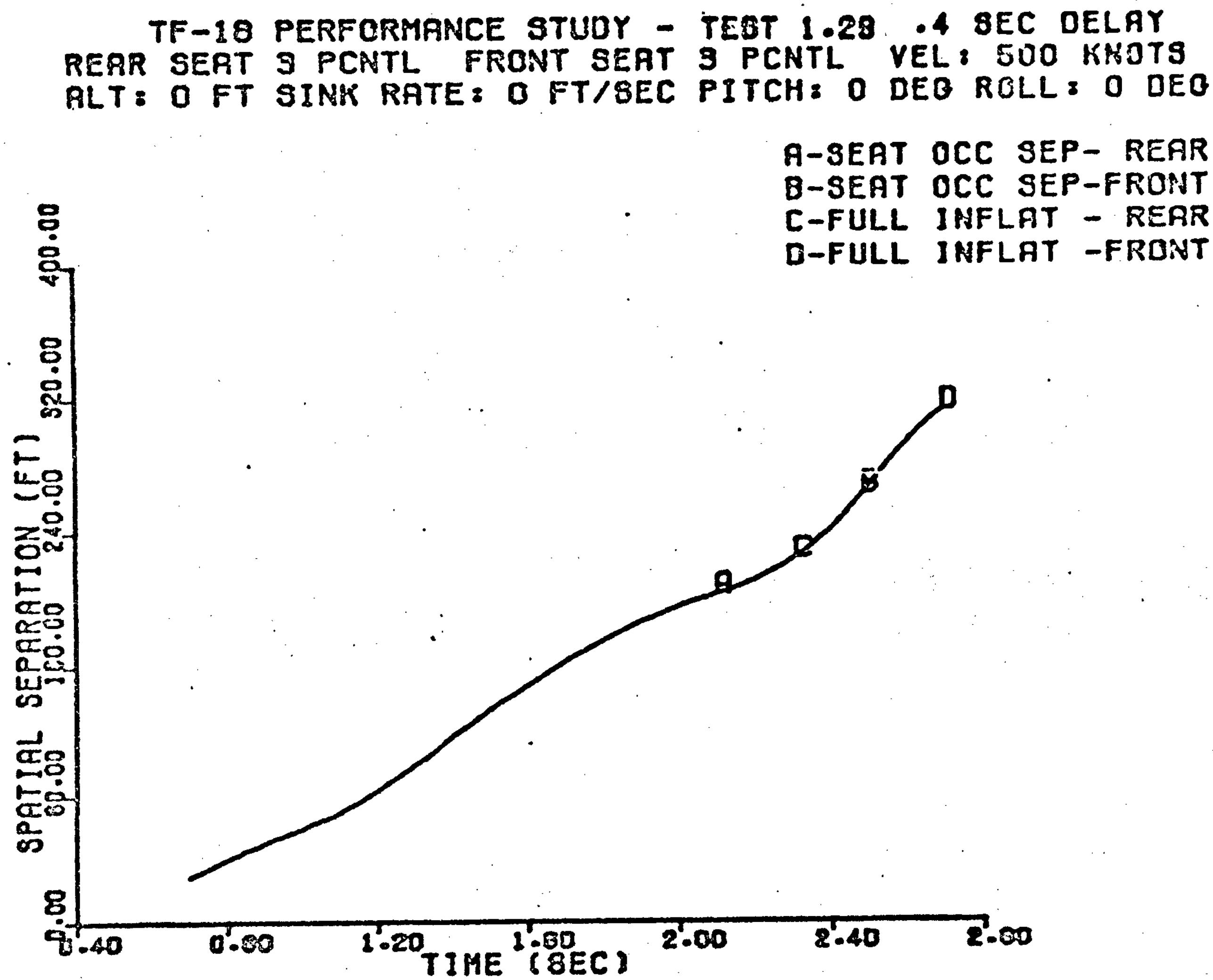

TF-18 PERFORMANCE STUDY - TEST 1.28 .4 SEC DELAY
REAR SEAT 3 PCNTL FRONT SEAT 3 PCNTL VEL: 500 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
80.00
160.00
240.00
320.00
400.00
TIME (SEC)
0.40
0.80
1.20
1.60
2.00
2.40
2.80
A
C
B
D

Figure D-58

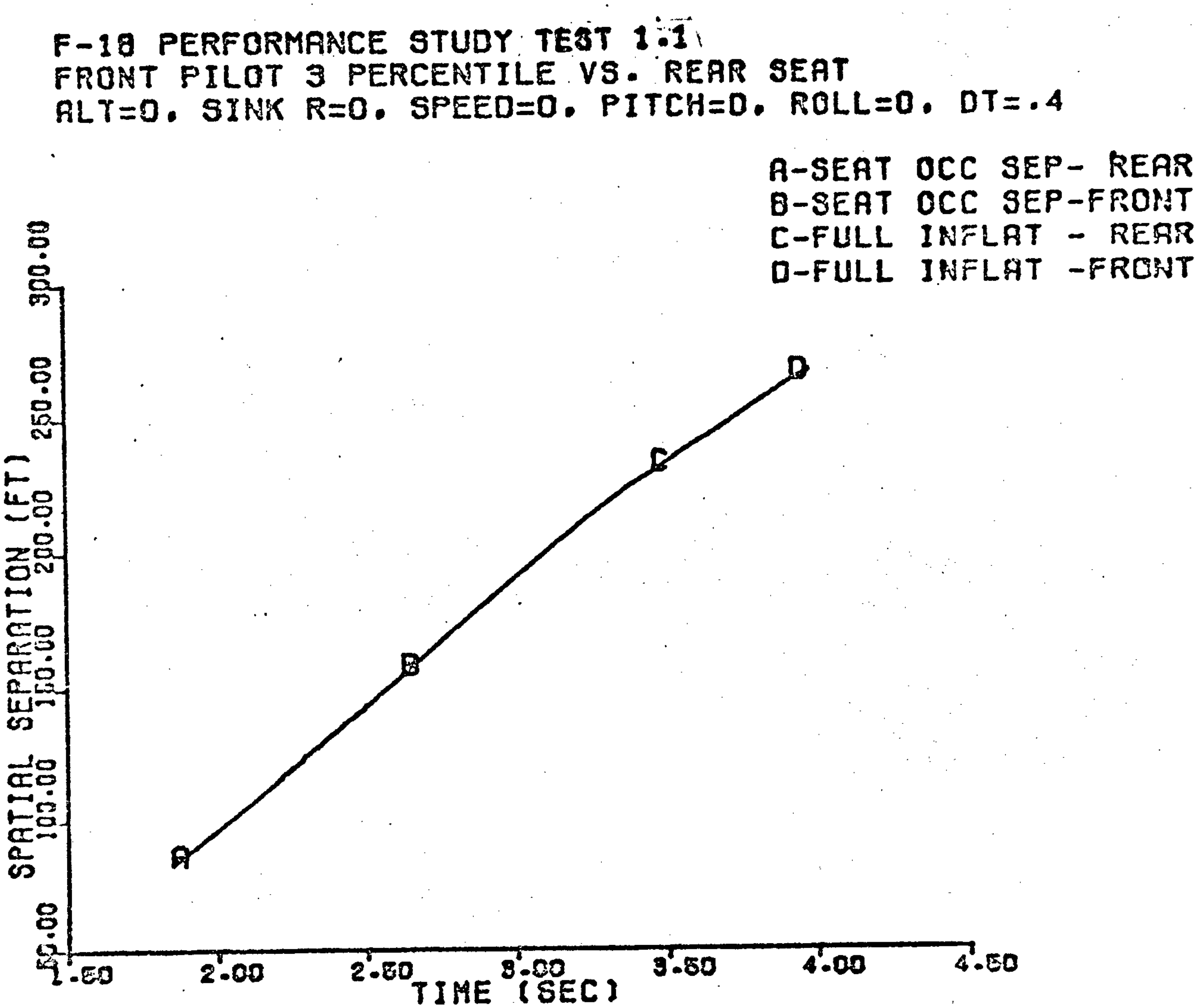

F-18 PERFORMANCE STUDY TEST 1.1
FRONT PILOT 3 PERCENTILE VS. REAR SEAT
ALT=0. SINK R=0. SPEED=0. PITCH=0. ROLL=0. DT=.4
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
50.00
100.00
150.00
200.00
250.00
300.00
TIME (SEC)
1.50
2.00
2.50
3.00
3.50
4.00
4.50
A
B
C
D

Figure D-59

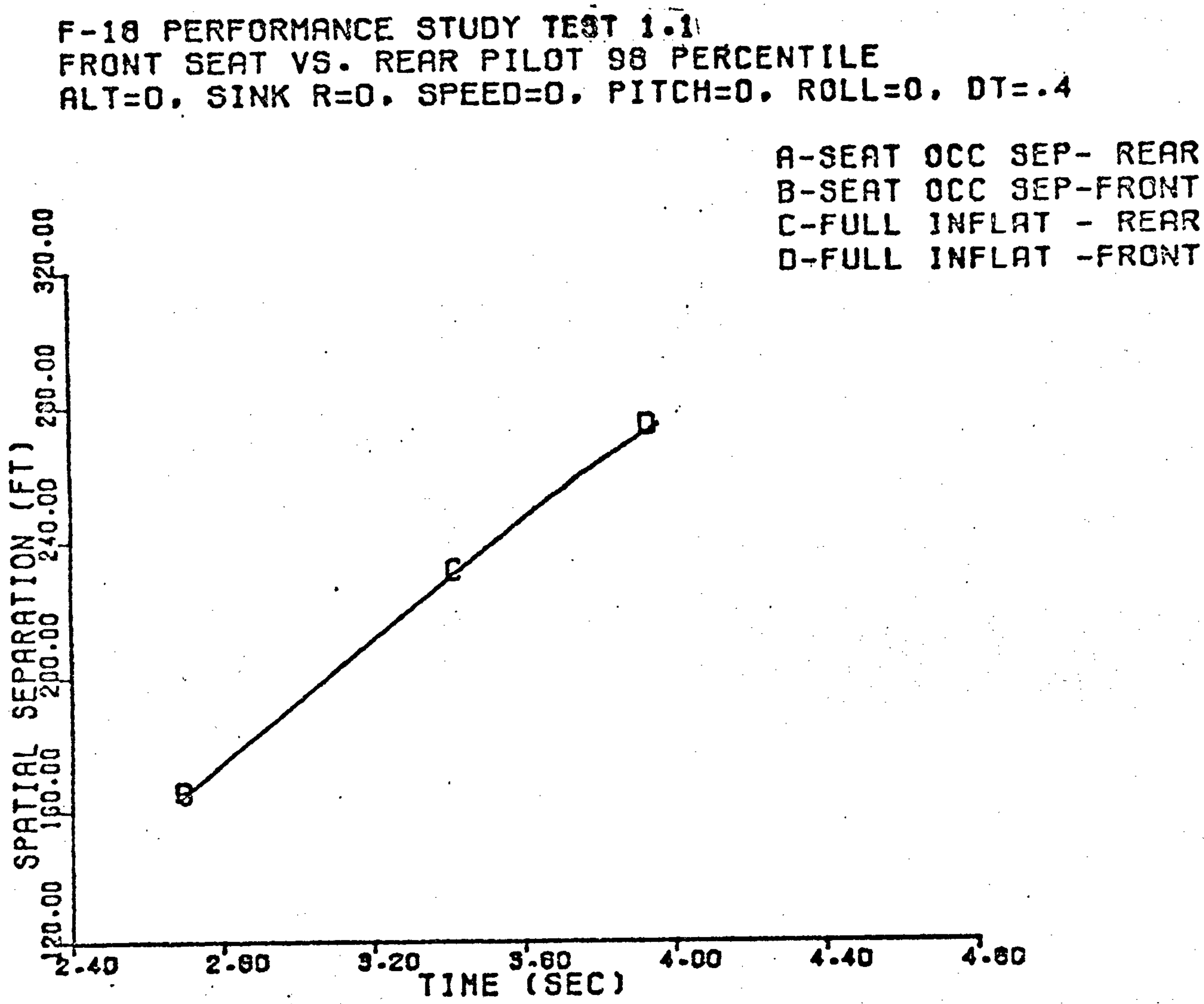

F-18 PERFORMANCE STUDY TEST 1.1
FRONT SEAT VS. REAR PILOT 98 PERCENTILE
ALT=0. SINK R=0. SPEED=0. PITCH=0. ROLL=0. DT=.4
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
120.00
160.00
200.00
240.00
280.00
320.00
TIME (SEC)
2.40
2.80
3.20
3.60
4.00
4.40
4.80
B
C
D

Figure D-60

F-18 PERFORMANCE STUDY: TEST 1.2
FRONT PILOT 3 PERCENTILE VS. REAR SEAT
ALT=0, SINK R=0, SPEED=200, PITCH=0, DT=.4

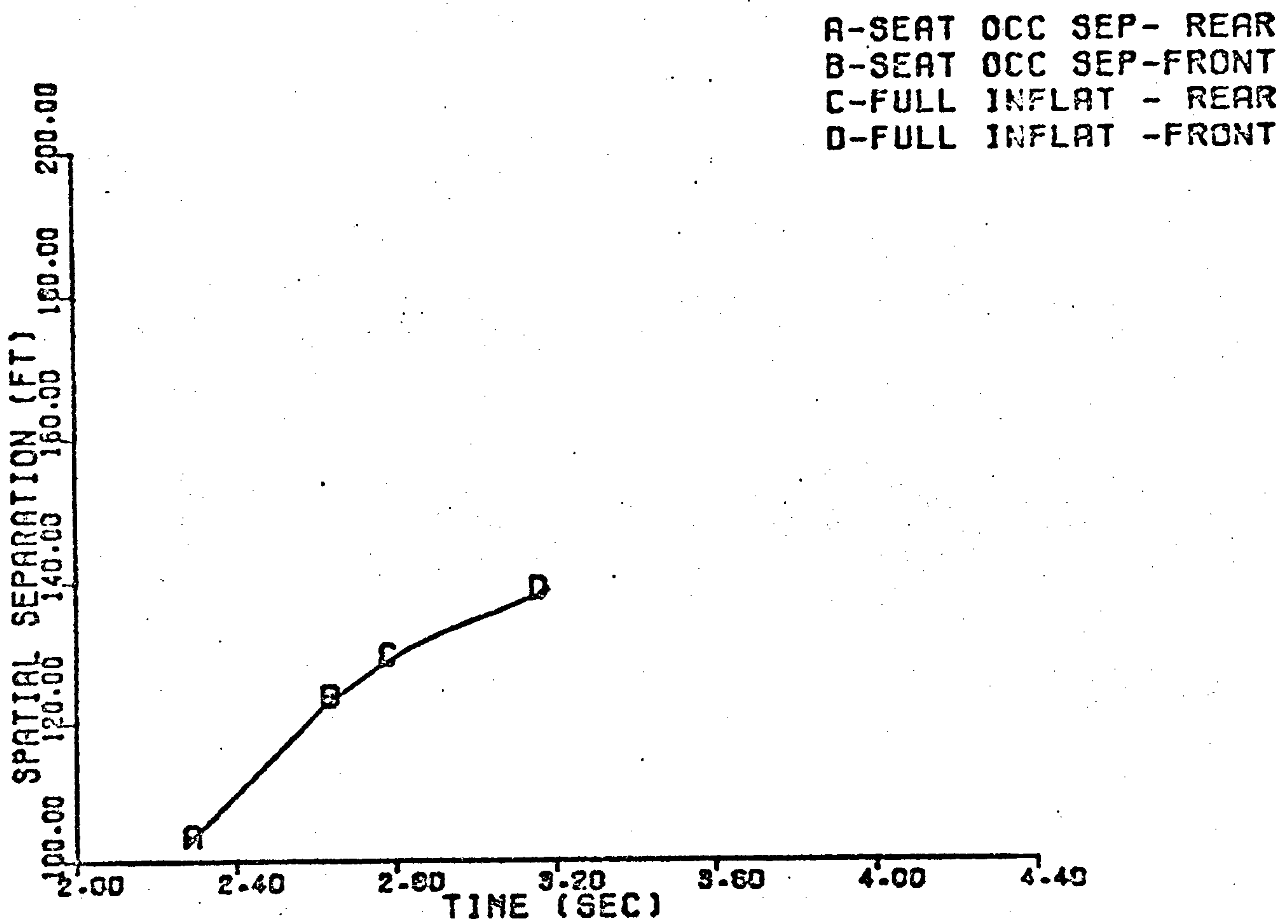


Figure D-61

F-18 PERFORMANCE STUDY TEST 1.2
REAR PILOT 98 PERCENTILE VS. FRONT SEAT
ALT=0. SINK R=0. SPEED=200. PITCH=0. DT=.4

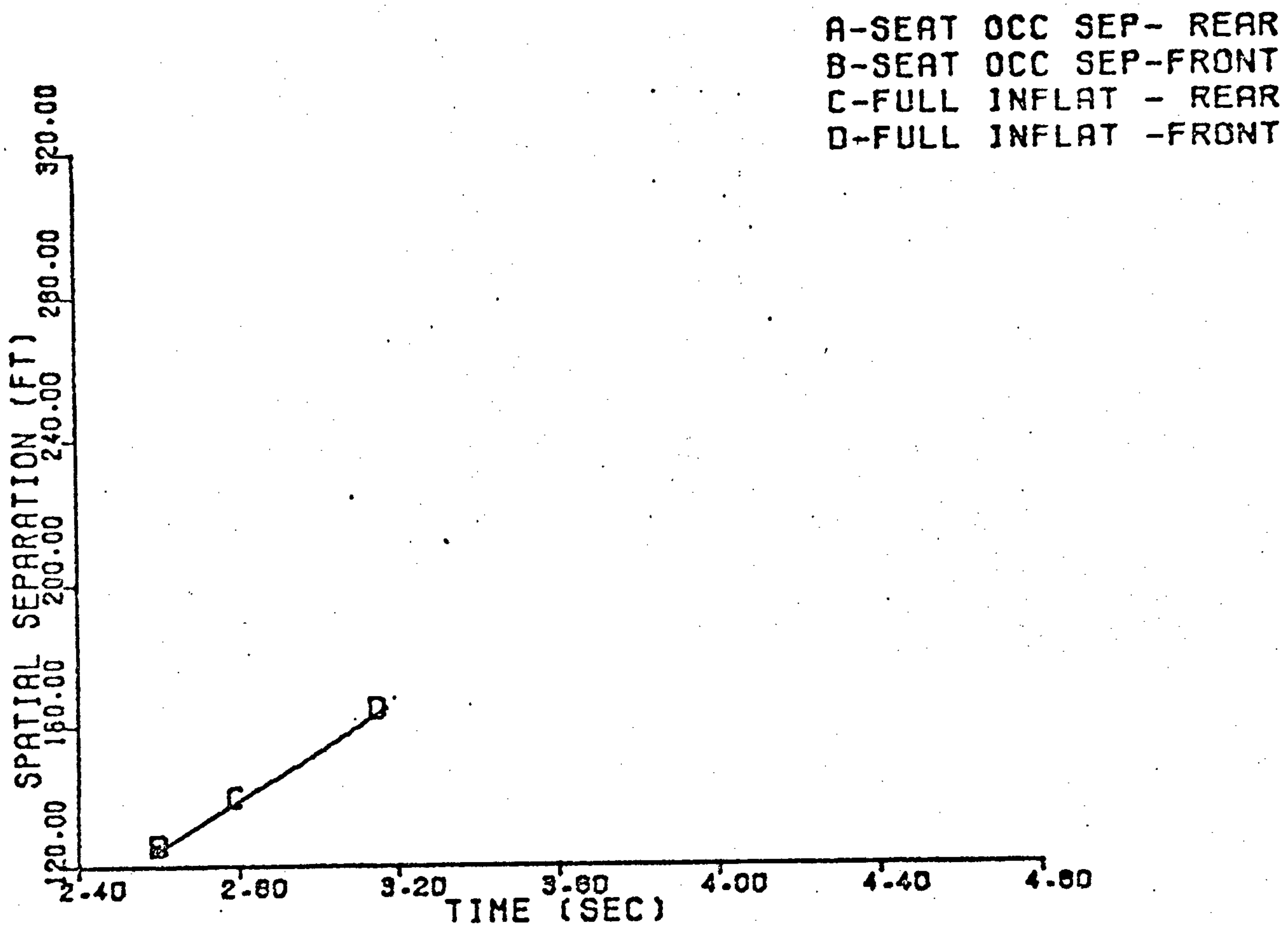


Figure D-62

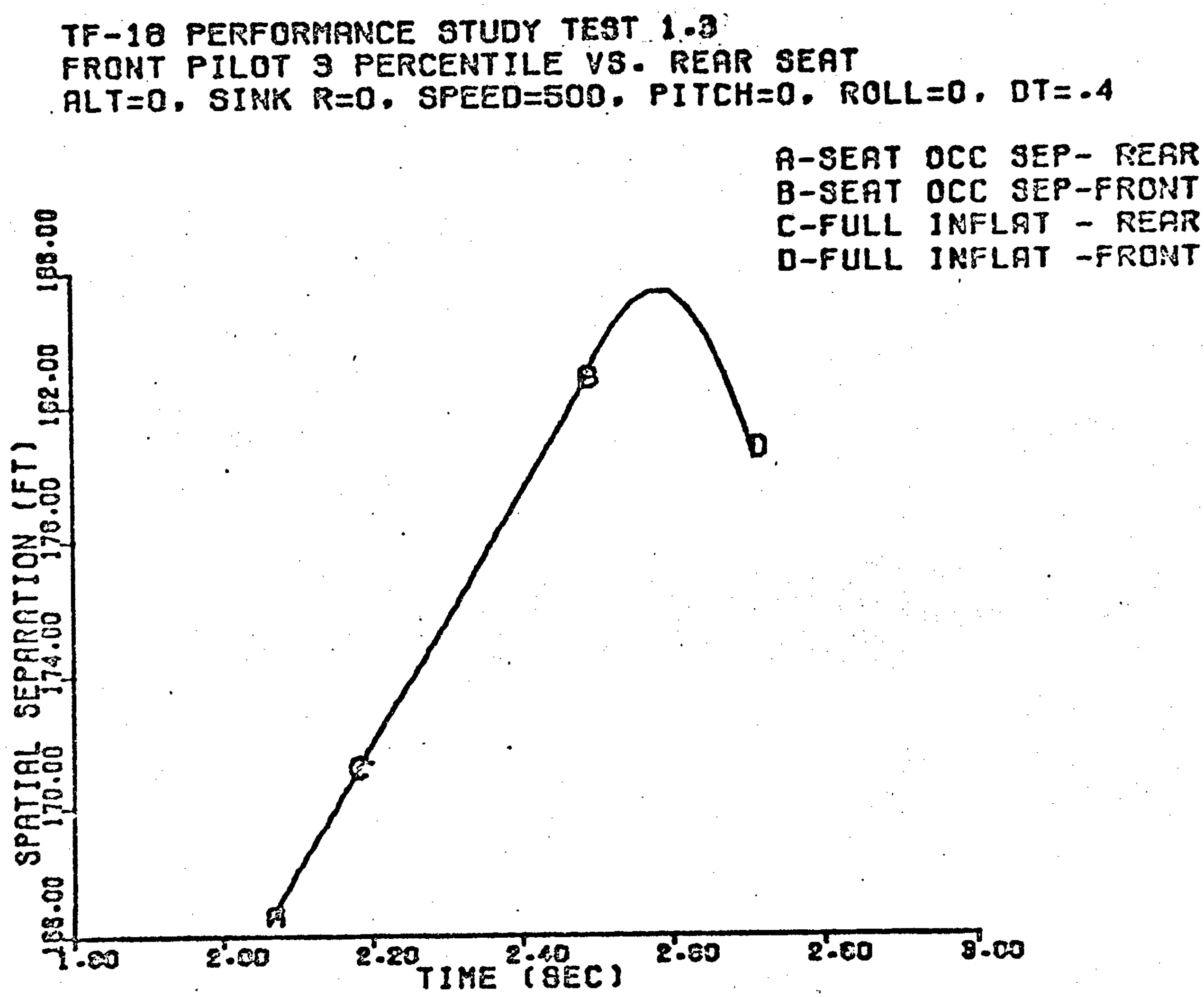

TF-18 PERFORMANCE STUDY TEST 1.3
FRONT PILOT 3 PERCENTILE VS. REAR SEAT
ALT=0, SINK R=0, SPEED=500, PITCH=0, ROLL=0, DT=.4
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
TIME (SEC)

Figure D-63

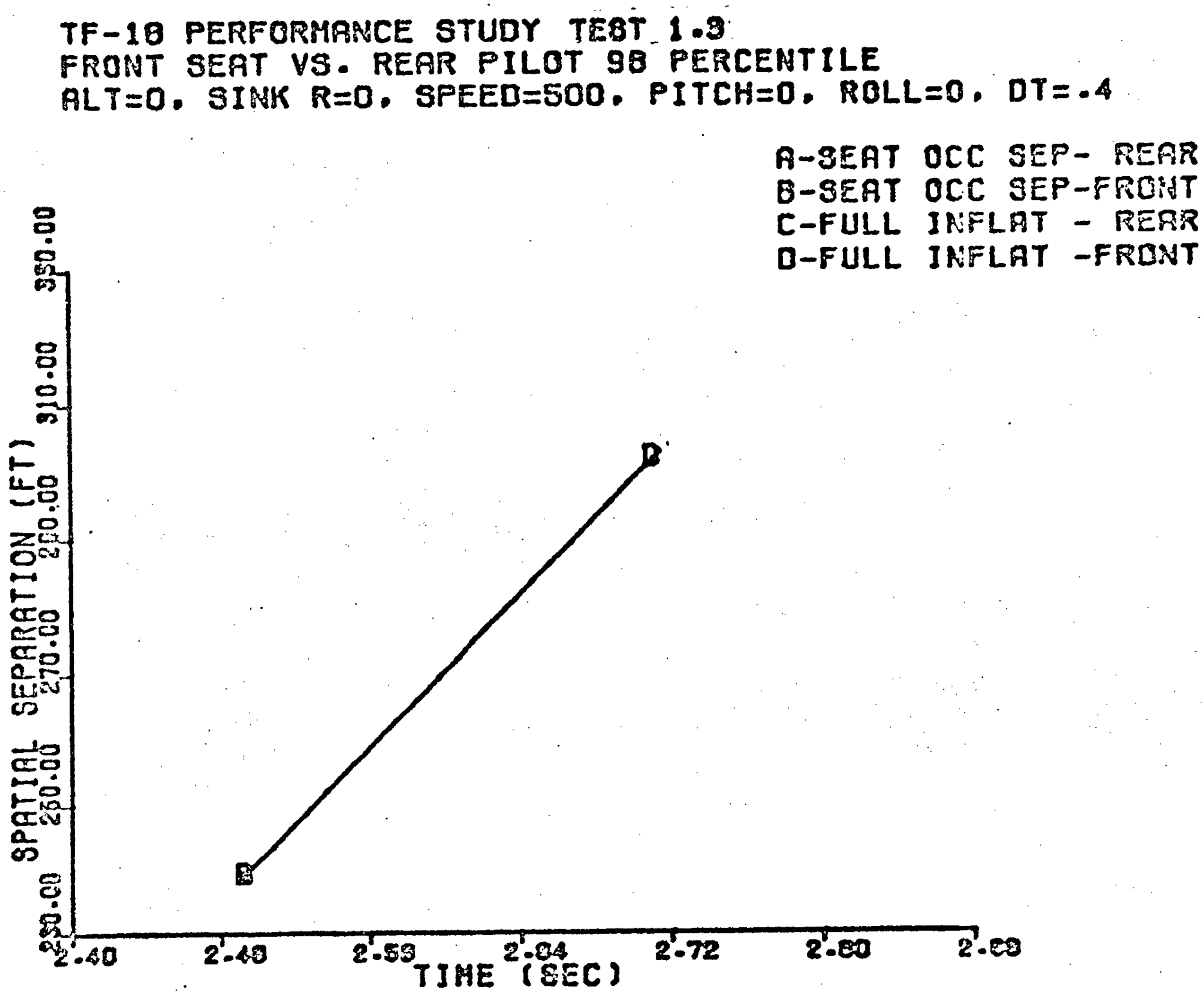

TF-18 PERFORMANCE STUDY TEST 1.3
FRONT SEAT VS. REAR PILOT 98 PERCENTILE
ALT=0. SINK R=0. SPEED=500. PITCH=0. ROLL=0. DT=.4
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
250.00
260.00
270.00
280.00
290.00
300.00
TIME (SEC)
2.40
2.48
2.56
2.64
2.72
2.80
2.88
B
D

Figure D-64

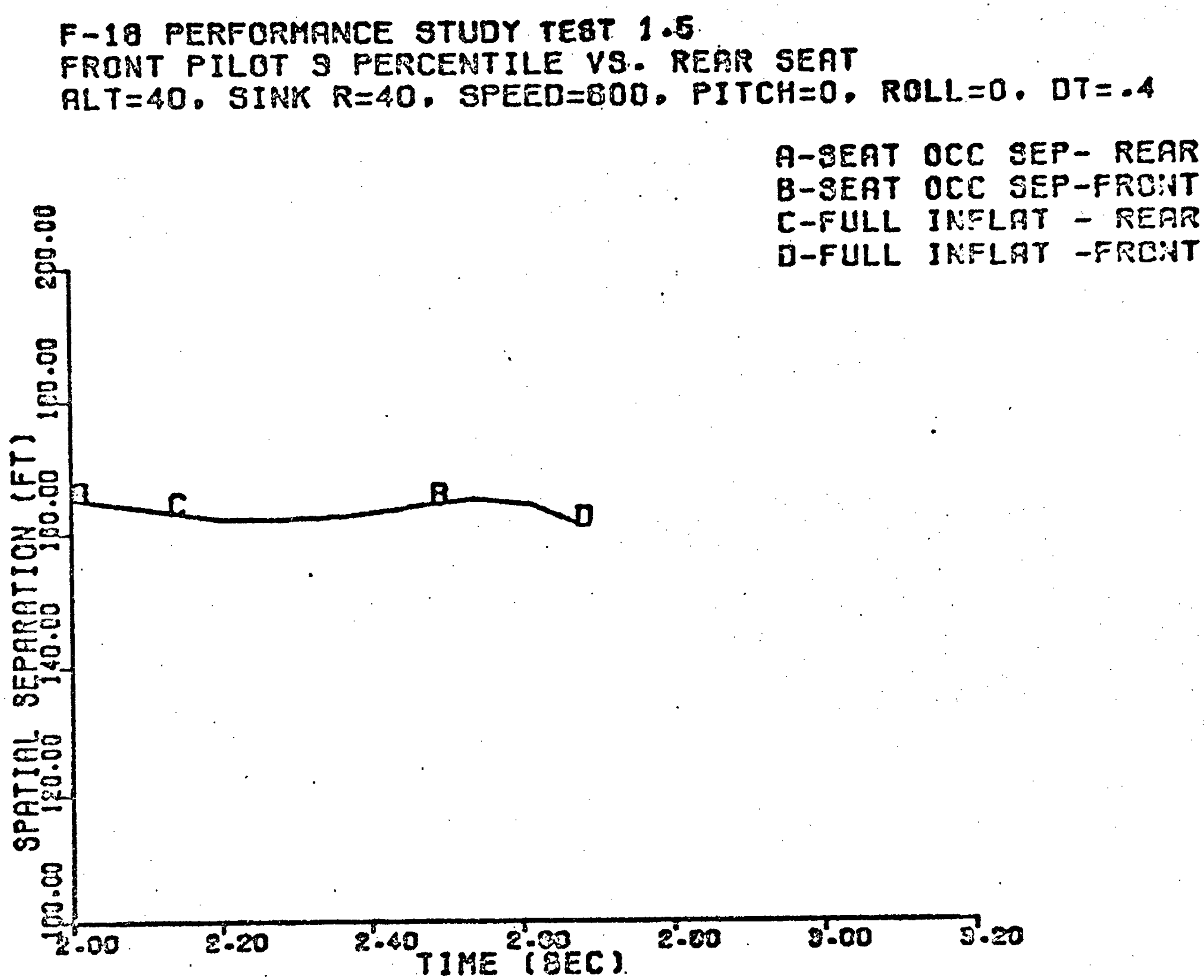

F-18 PERFORMANCE STUDY TEST 1.5
FRONT PILOT 3 PERCENTILE VS. REAR SEAT
ALT=40. SINK R=40. SPEED=800. PITCH=0. ROLL=0. DT=.4
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
TIME (SEC)

Figure D-65

F-18 PERFORMANCE STUDY TEST 1.5
FRONT SEAT VS. REAR PILOT 98 PERCENTILE
ALT=40. SINK R=40. SPEED=600. PITCH=0. ROLL=0. DT=.4

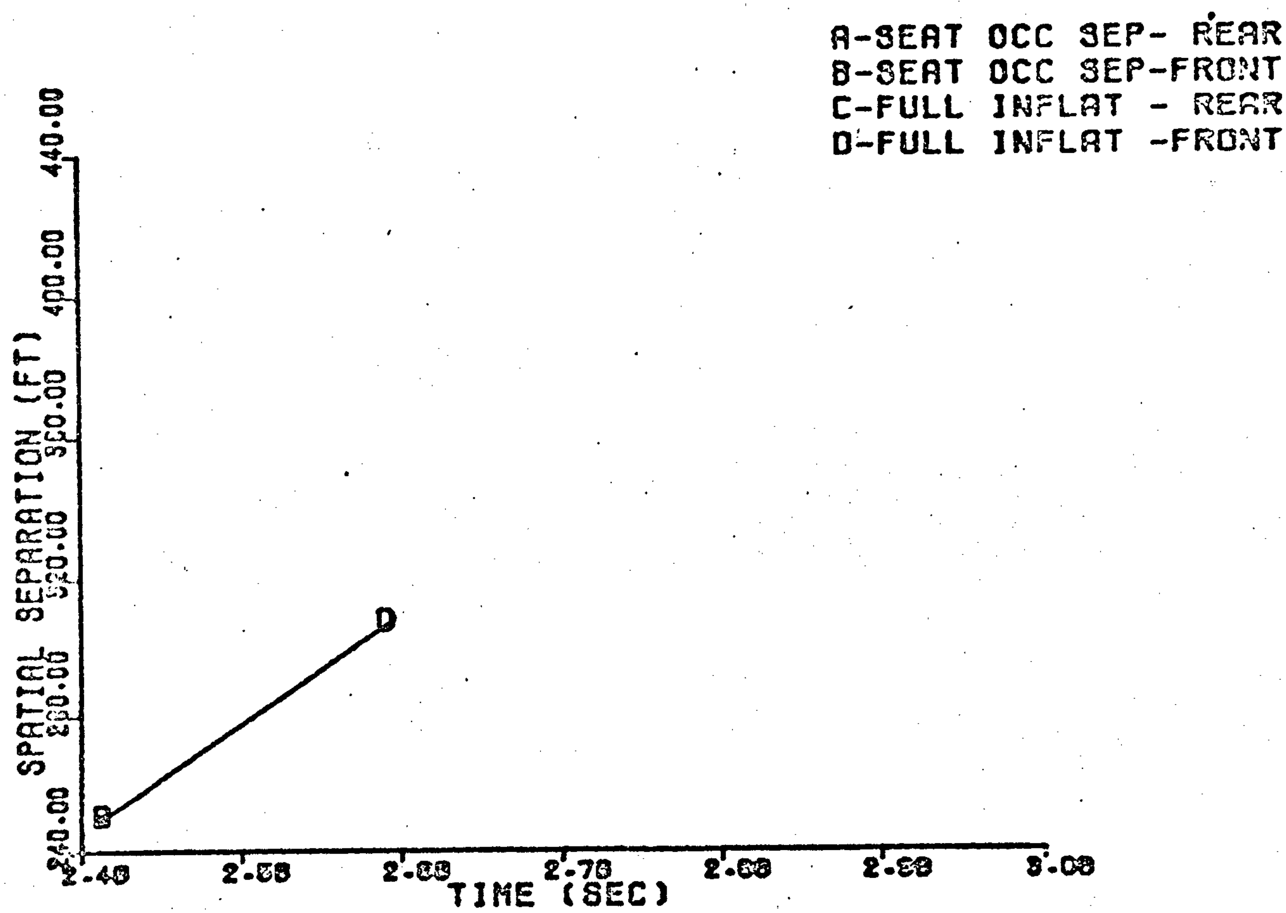


Figure D-66

TF-18 PERFORMANCE STUDY TEST 1.8
FRONT PILOT 3 PERCENTILE VS. REAR SEAT
ALT=384. SINK R=0. SPEED=130. PITCH=0. ROLL=180. DT=.4

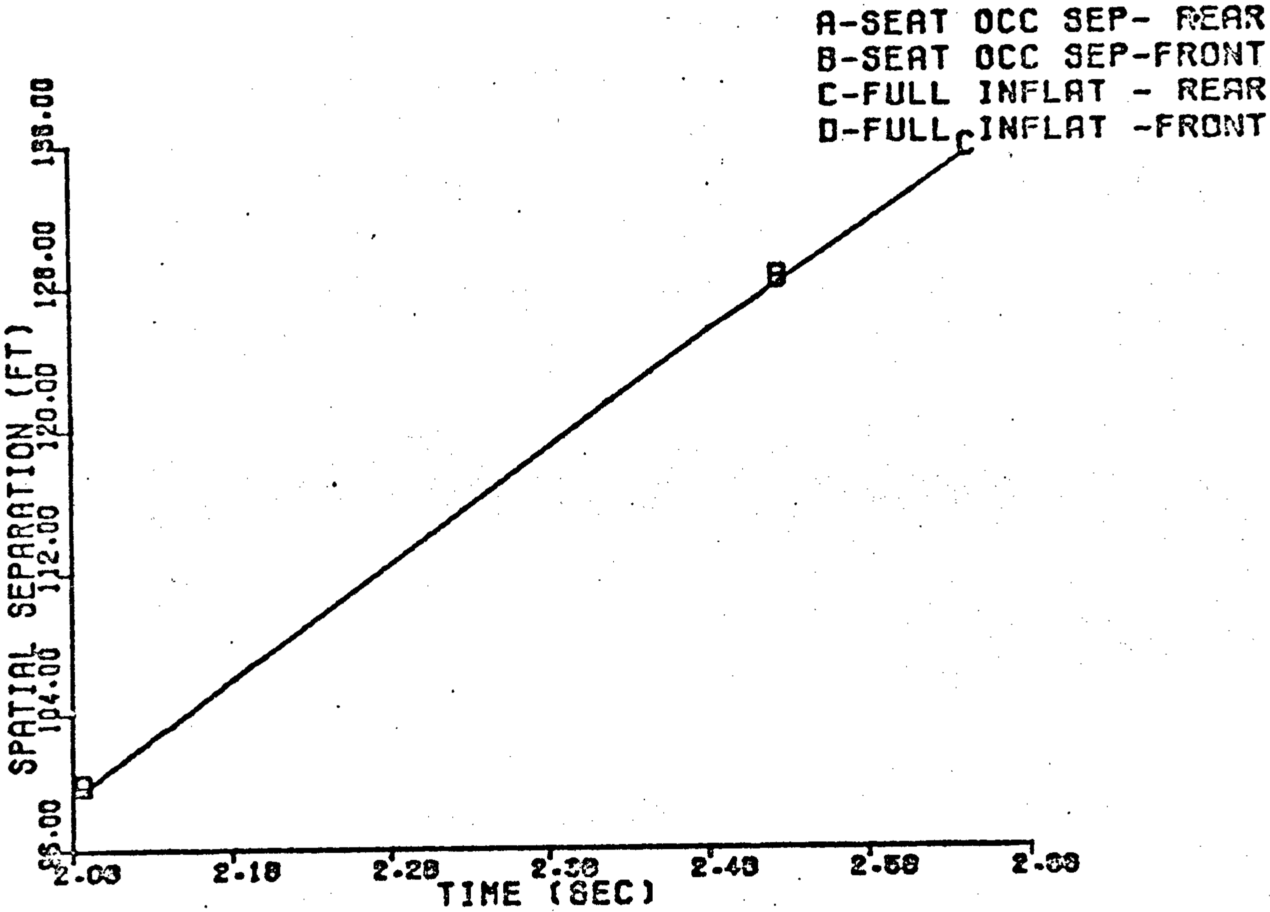
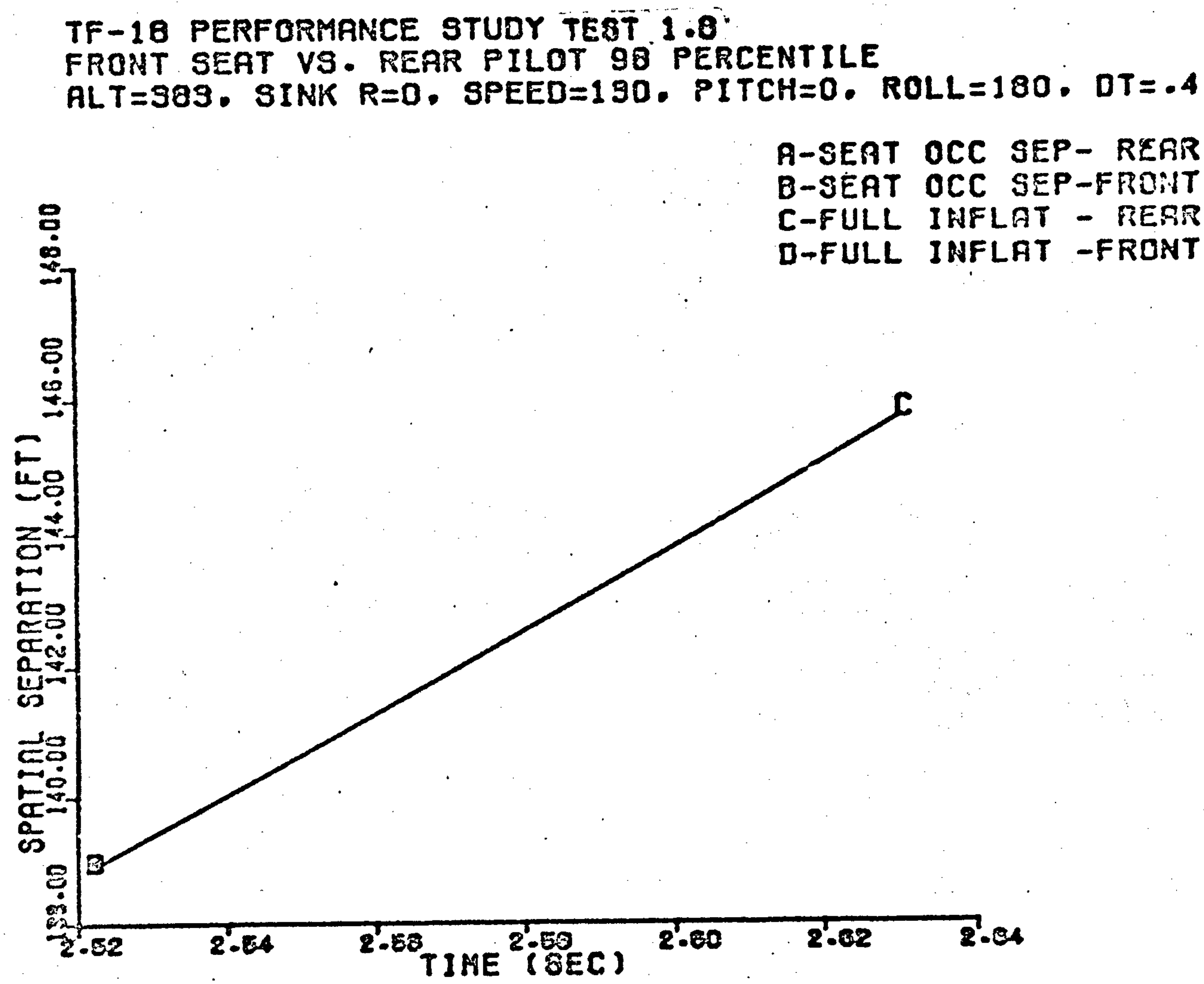


Figure D-67



TF-18 PERFORMANCE STUDY TEST 1.8
FRONT SEAT VS. REAR PILOT 98 PERCENTILE
ALT=383. SINK R=0. SPEED=190. PITCH=0. ROLL=180. DT=.4
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
148.00
146.00
144.00
142.00
140.00
138.00
2.52
2.54
2.56
2.58
2.60
2.62
2.64
TIME (SEC)
C
B

Figure D-68

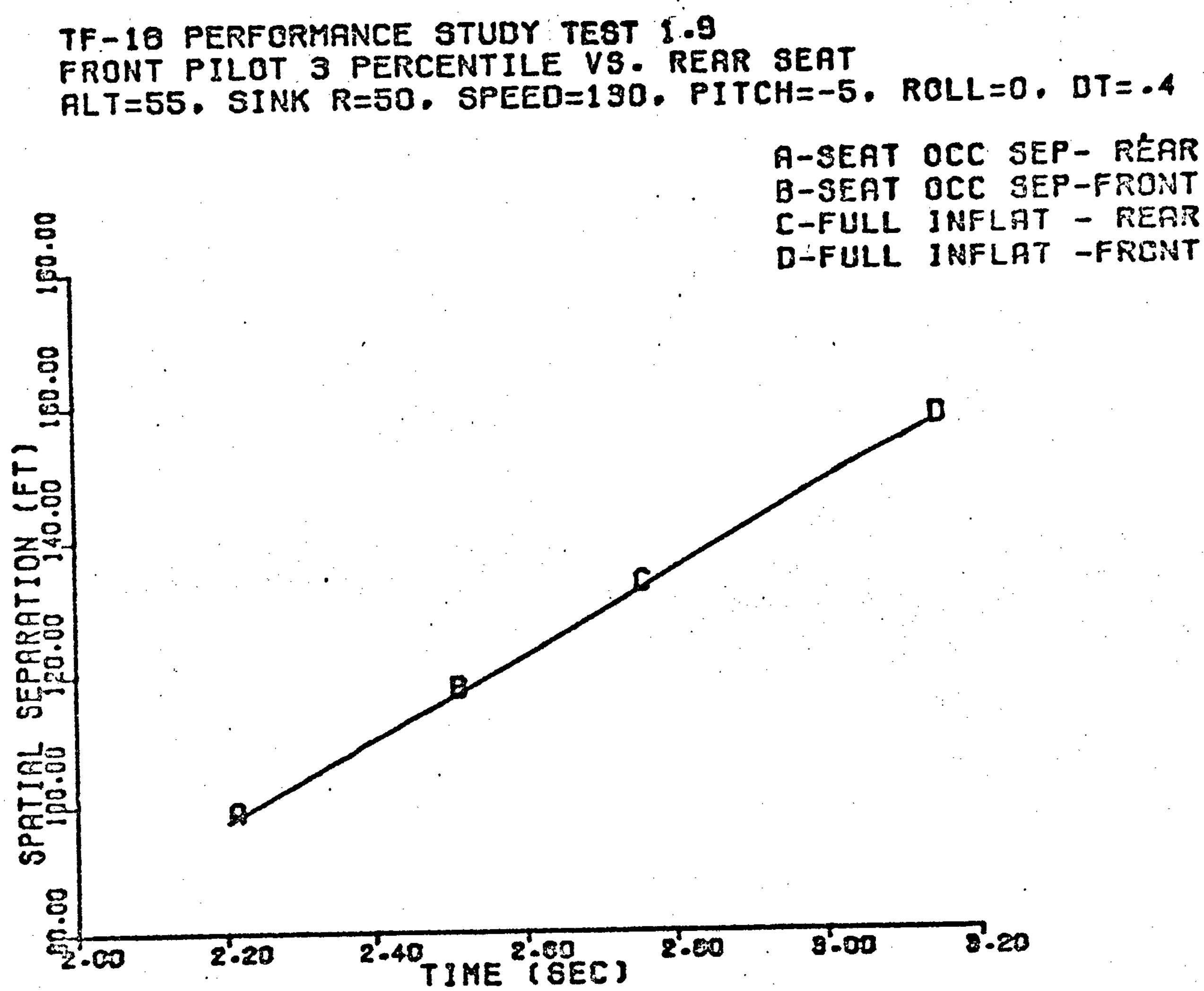

TF-18 PERFORMANCE STUDY TEST 1.9
FRONT PILOT 3 PERCENTILE VS. REAR SEAT
ALT=55. SINK R=50. SPEED=130. PITCH=-5. ROLL=0. DT=.4
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
100.00
120.00
140.00
160.00
TIME (SEC)
2.20
2.40

Figure D-69

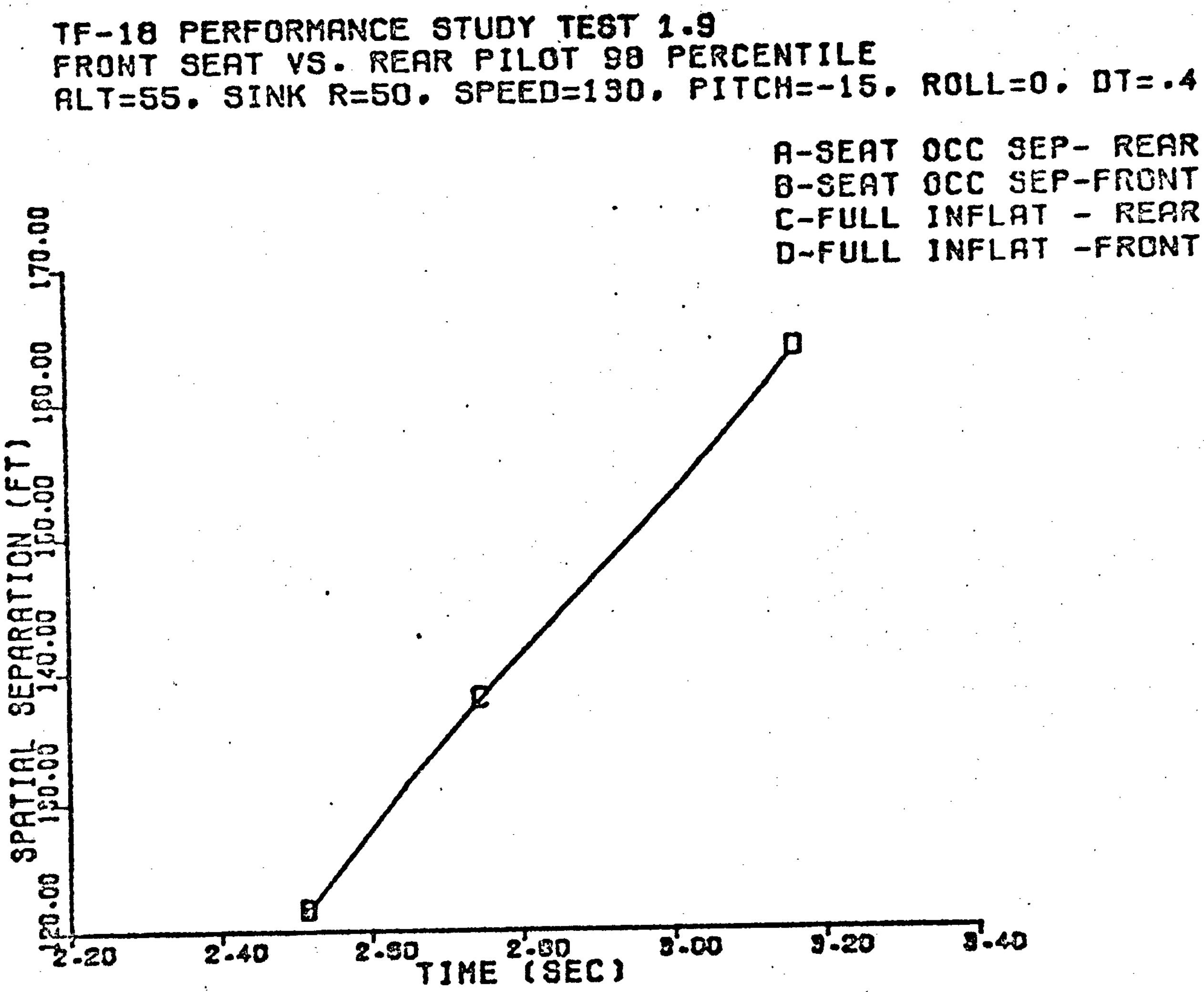
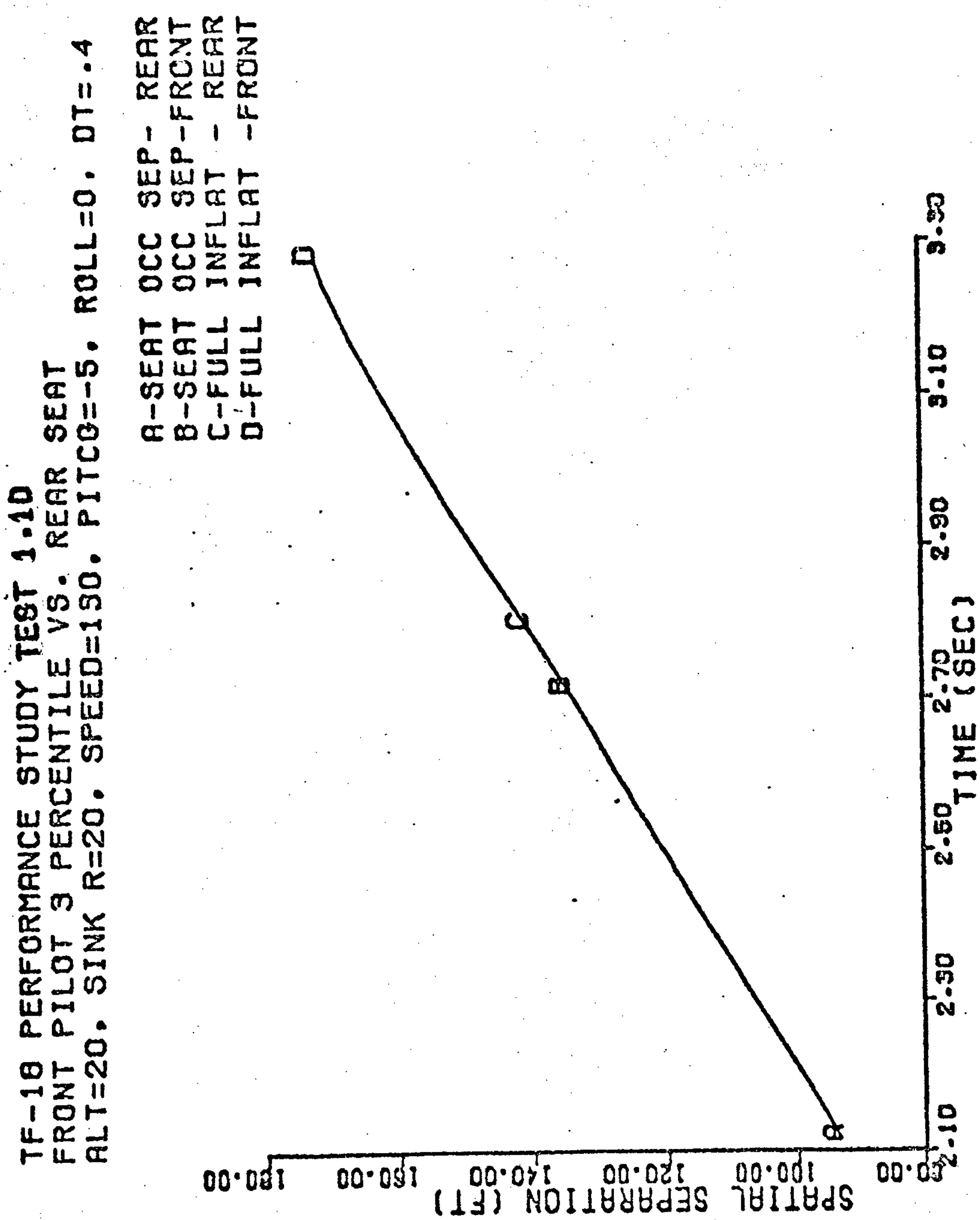

TF-18 PERFORMANCE STUDY TEST 1.9
FRONT SEAT VS. REAR PILOT 98 PERCENTILE
ALT=55. SINK R=50. SPEED=130. PITCH=-15. ROLL=0. DT=.4
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
120.00
130.00
140.00
150.00
160.00
170.00
TIME (SEC)
2.20
2.40
2.60
2.80
3.00
3.20
3.40

Figure D-70



TF-18 PERFORMANCE STUDY TEST 1.1D
FRONT PILOT 3 PERCENTILE VS. REAR SEAT
ALT=20. SINK R=20. SPEED=130. PITCO=-5. ROLL=0. DT=.4
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
80.00
100.00
120.00
140.00
160.00
180.00
TIME (SEC)
2.10
2.30
2.50
2.70
2.90
3.10
3.30

Figure D-71

TF-18 PERFORMANCE STUDY TEST 1.10
FRONT SEAT VS. REAR PILOT 98 PERCENTILE
ALT=20. SINK R=20. SPEED=130. PITCH=-5. ROLL=0. DT=.4

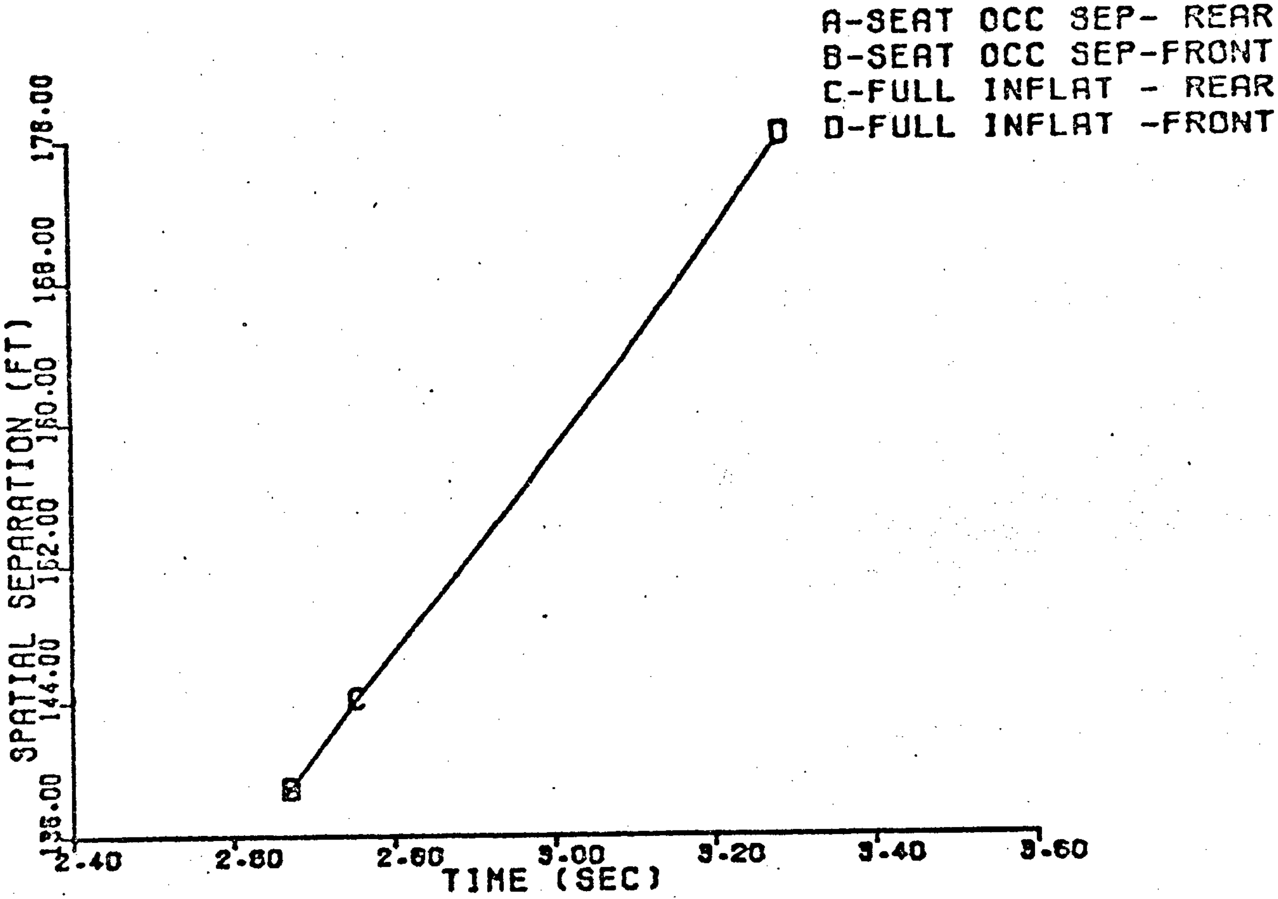
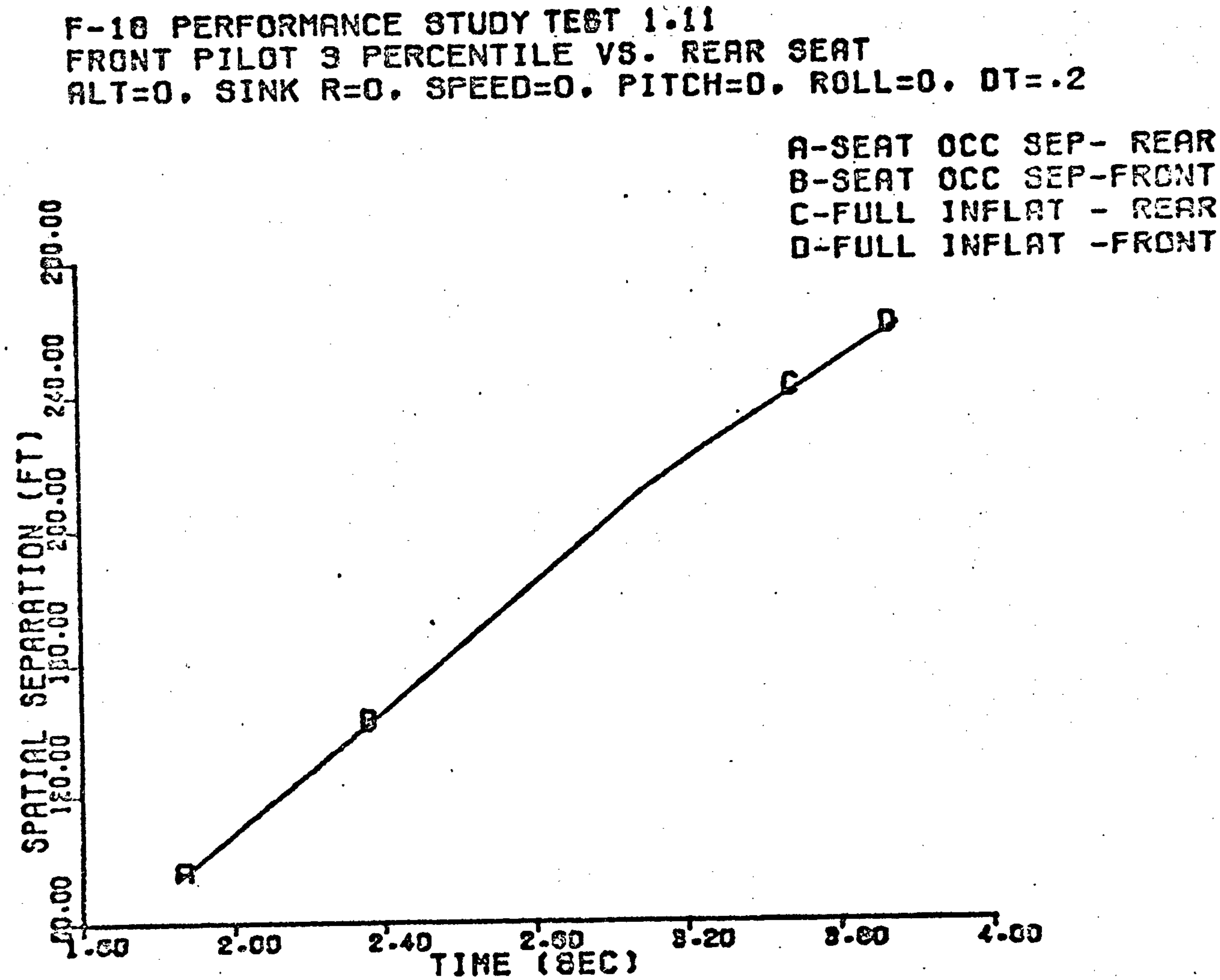


Figure D-72



F-18 PERFORMANCE STUDY TEST 1.11
FRONT PILOT 3 PERCENTILE VS. REAR SEAT
ALT=0. SINK R=0. SPEED=0. PITCH=0. ROLL=0. DT=.2
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
200.00
240.00
TIME (SEC)
2.00
2.40
4.00

Figure D-73

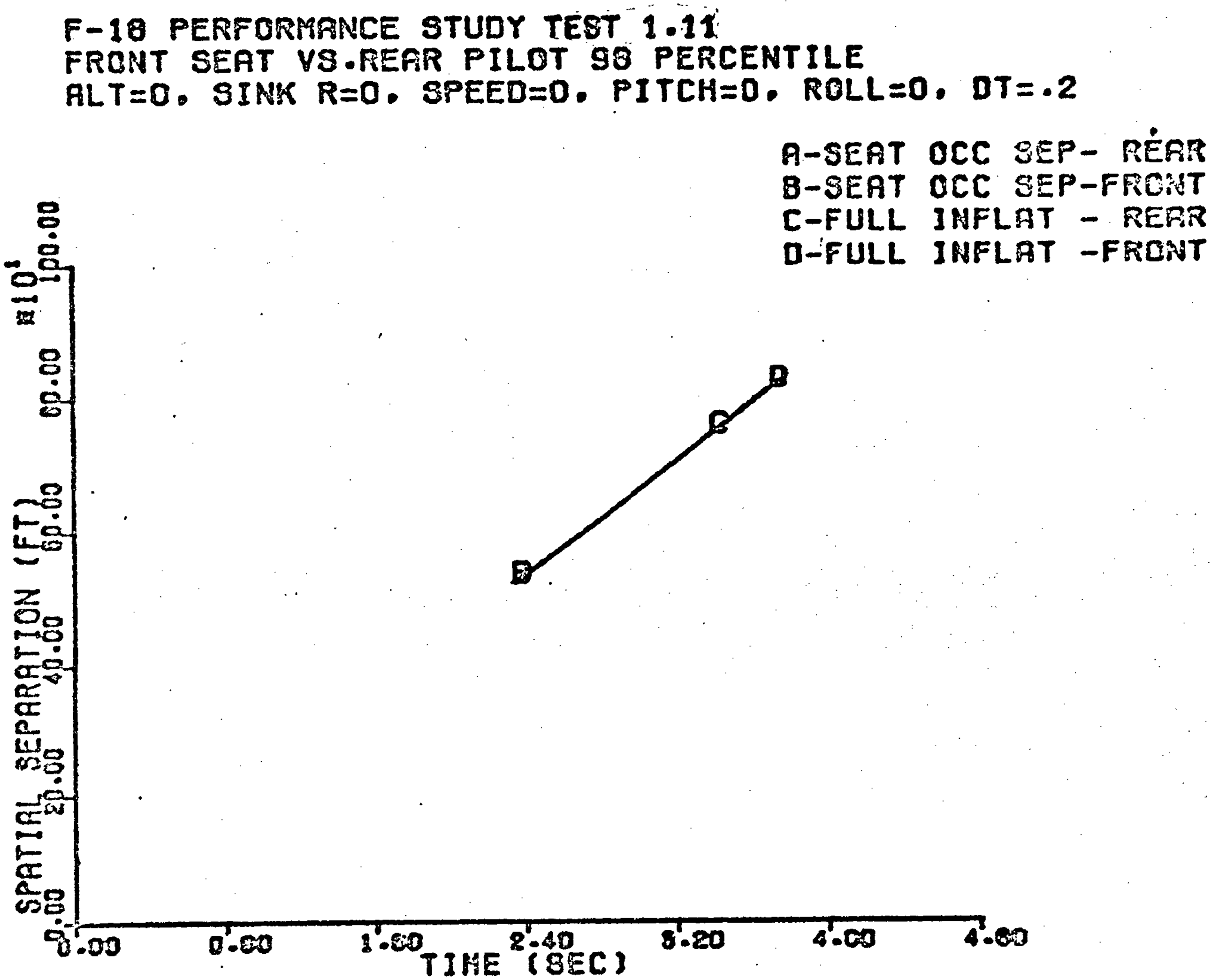

F-18 PERFORMANCE STUDY TEST 1.11
FRONT SEAT VS.REAR PILOT 98 PERCENTILE
ALT=0. SINK R=0. SPEED=0. PITCH=0. ROLL=0. DT=.2
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
*10¹
0.00
20.00
40.00
60.00
80.00
100.00
TIME (SEC)
0.00
0.80
1.60
2.40
3.20
4.00
4.80
B
C
D

Figure D-74

F-18 PERFORMANCE STUDY TEST 1.12
FRONT PILOT 3 PERCENTILE VS. REAR SEAT
ALT=0. SINK R=0. SPEED=200. PITCH=0. ROLL=0. DT=.2

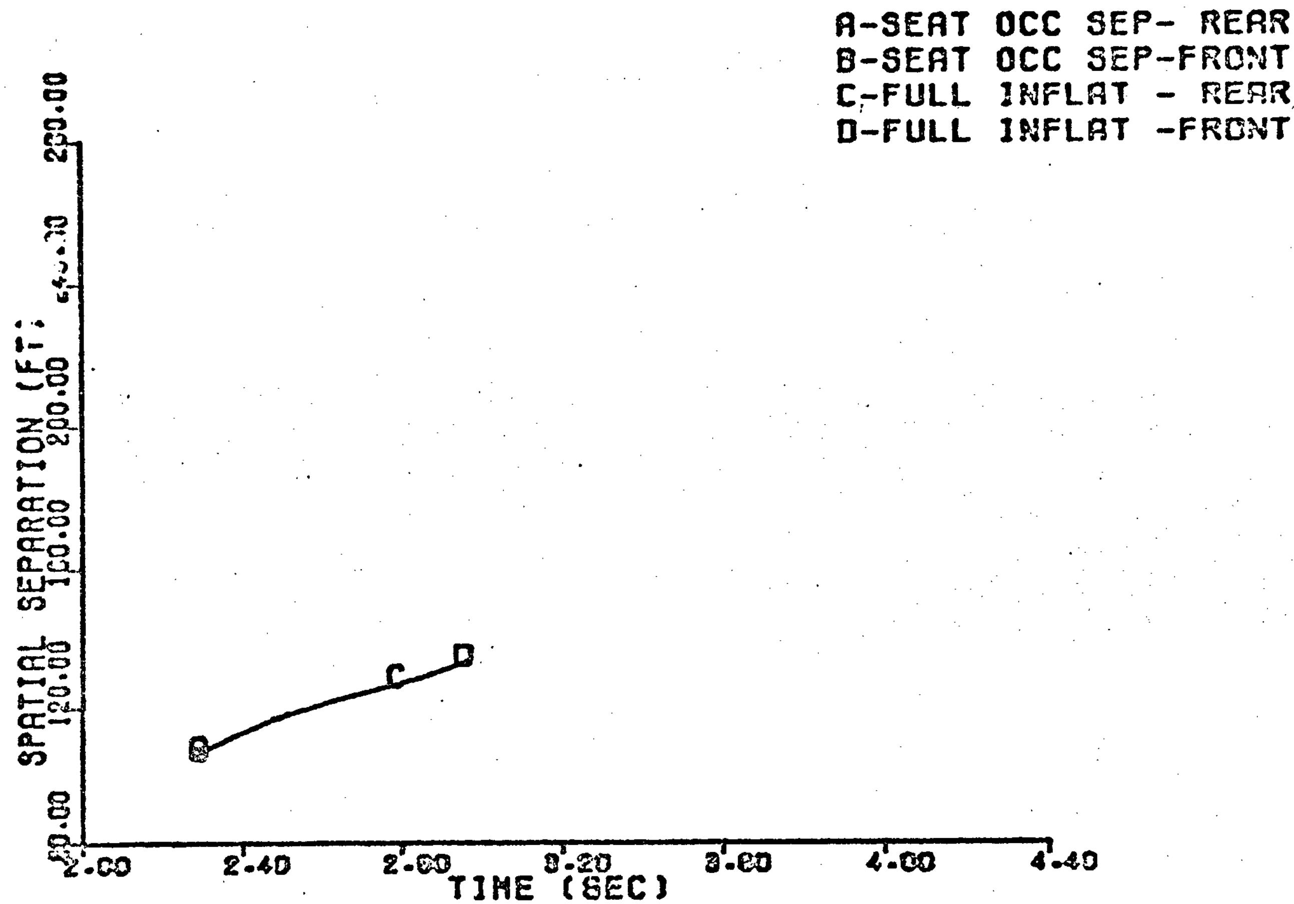


Figure D-75

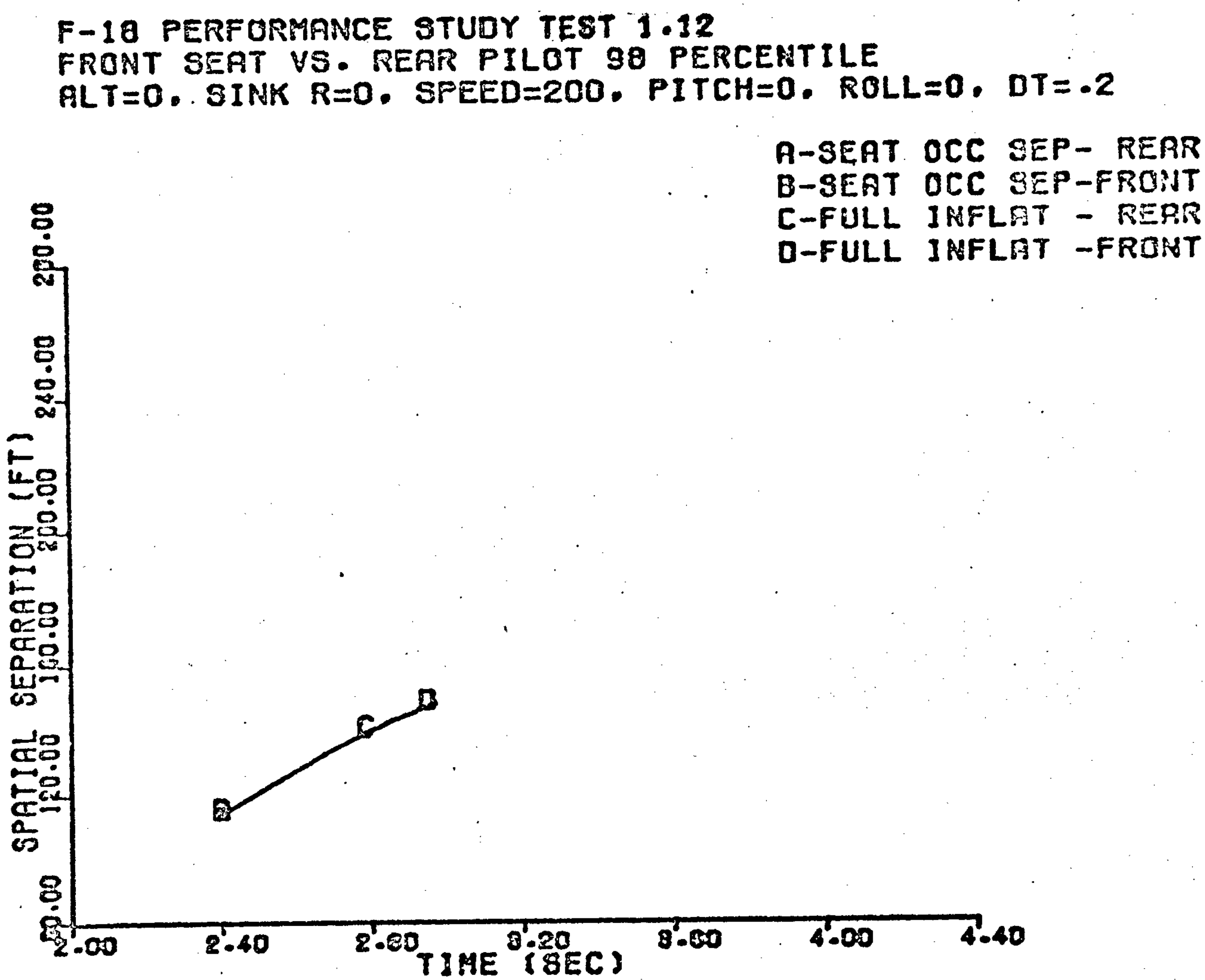

F-18 PERFORMANCE STUDY TEST 1.12
FRONT SEAT VS. REAR PILOT 98 PERCENTILE
ALT=0. SINK R=0. SPEED=200. PITCH=0. ROLL=0. DT=.2
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
TIME (SEC)
2.00
2.40
2.80
3.20
3.60
4.00
4.40

Figure D-76

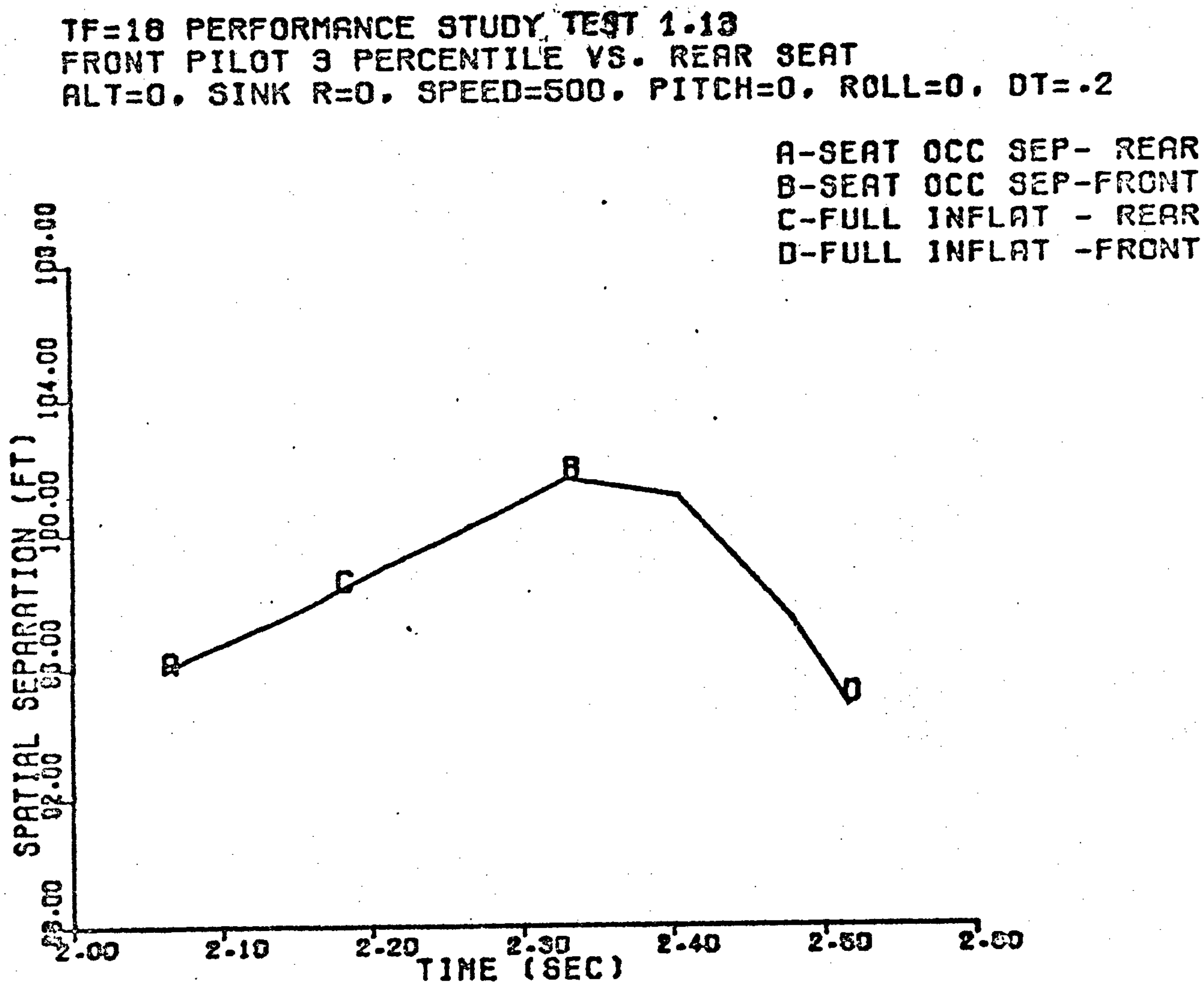

TF=18 PERFORMANCE STUDY TEST 1.13
FRONT PILOT 3 PERCENTILE VS. REAR SEAT
ALT=0. SINK R=0. SPEED=500. PITCH=0. ROLL=0. DT=.2
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
108.00
104.00
100.00
2.00
2.10
2.20
2.30
2.40
2.50
2.60
TIME (SEC)
A
B
C
D

Figure D-77

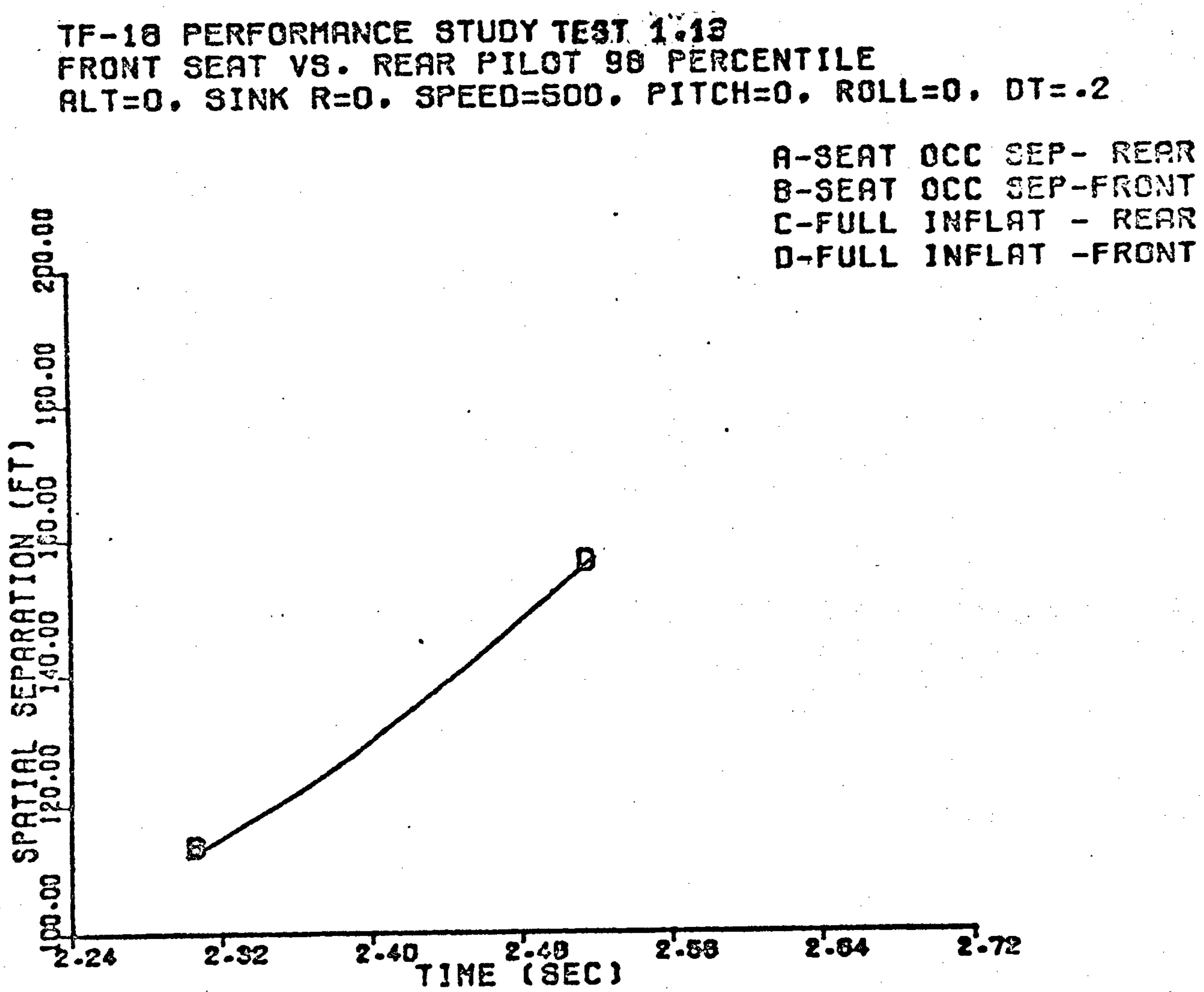

TF-18 PERFORMANCE STUDY TEST 1.13
FRONT SEAT VS. REAR PILOT 98 PERCENTILE
ALT=0. SINK R=0. SPEED=500. PITCH=0. ROLL=0. DT=.2
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
100.00
120.00
140.00
160.00
180.00
200.00
TIME (SEC)
2.24
2.32
2.40
2.48
2.56
2.64
2.72
B
D

Figure D-78

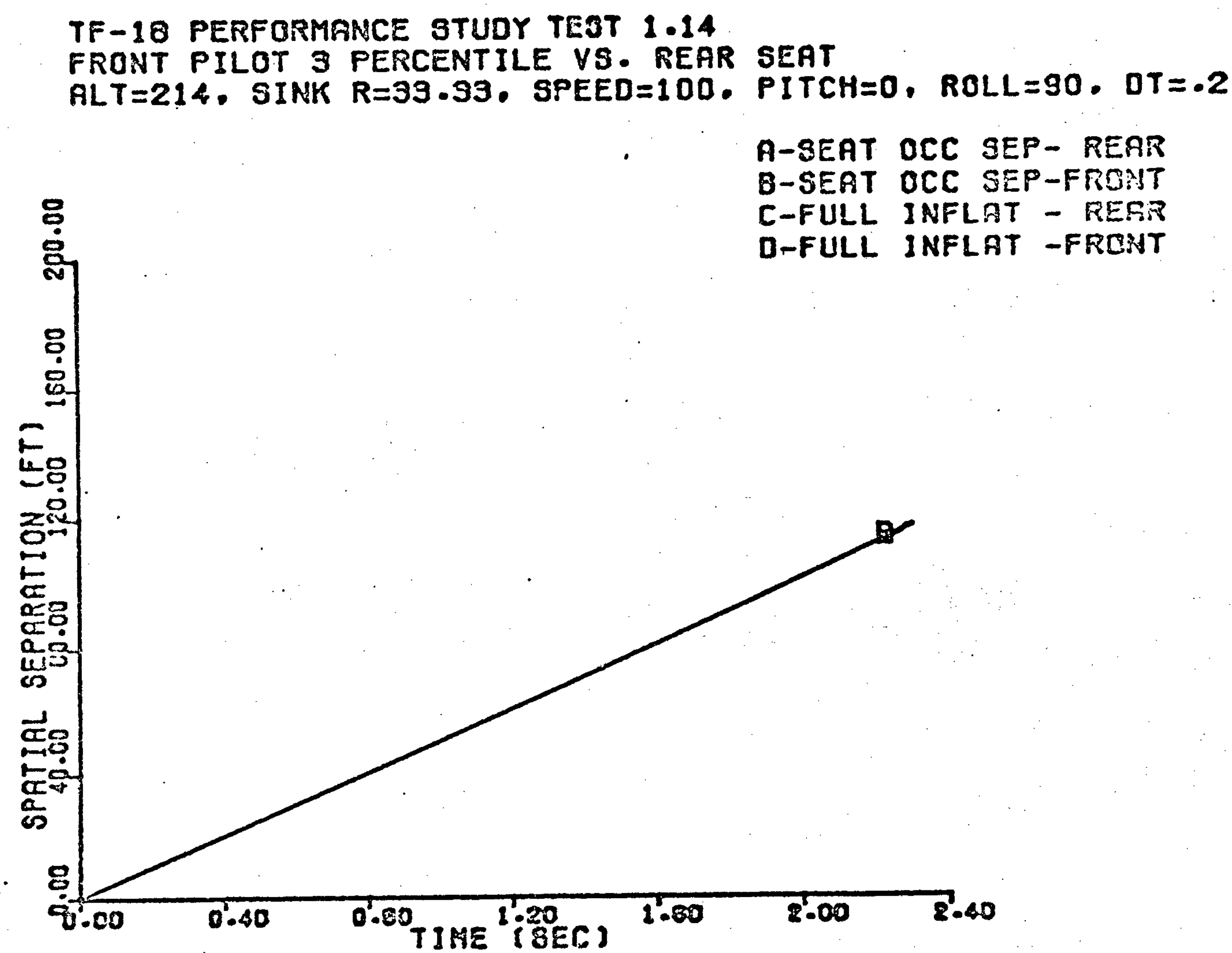

TF-18 PERFORMANCE STUDY TEST 1.14
FRONT PILOT 3 PERCENTILE VS. REAR SEAT
ALT=214. SINK R=33.33. SPEED=100. PITCH=0. ROLL=90. DT=.2
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
40.00
80.00
120.00
160.00
200.00
TIME (SEC)
0.00
0.40
0.80
1.20
1.60
2.00
2.40
B

Figure D-79

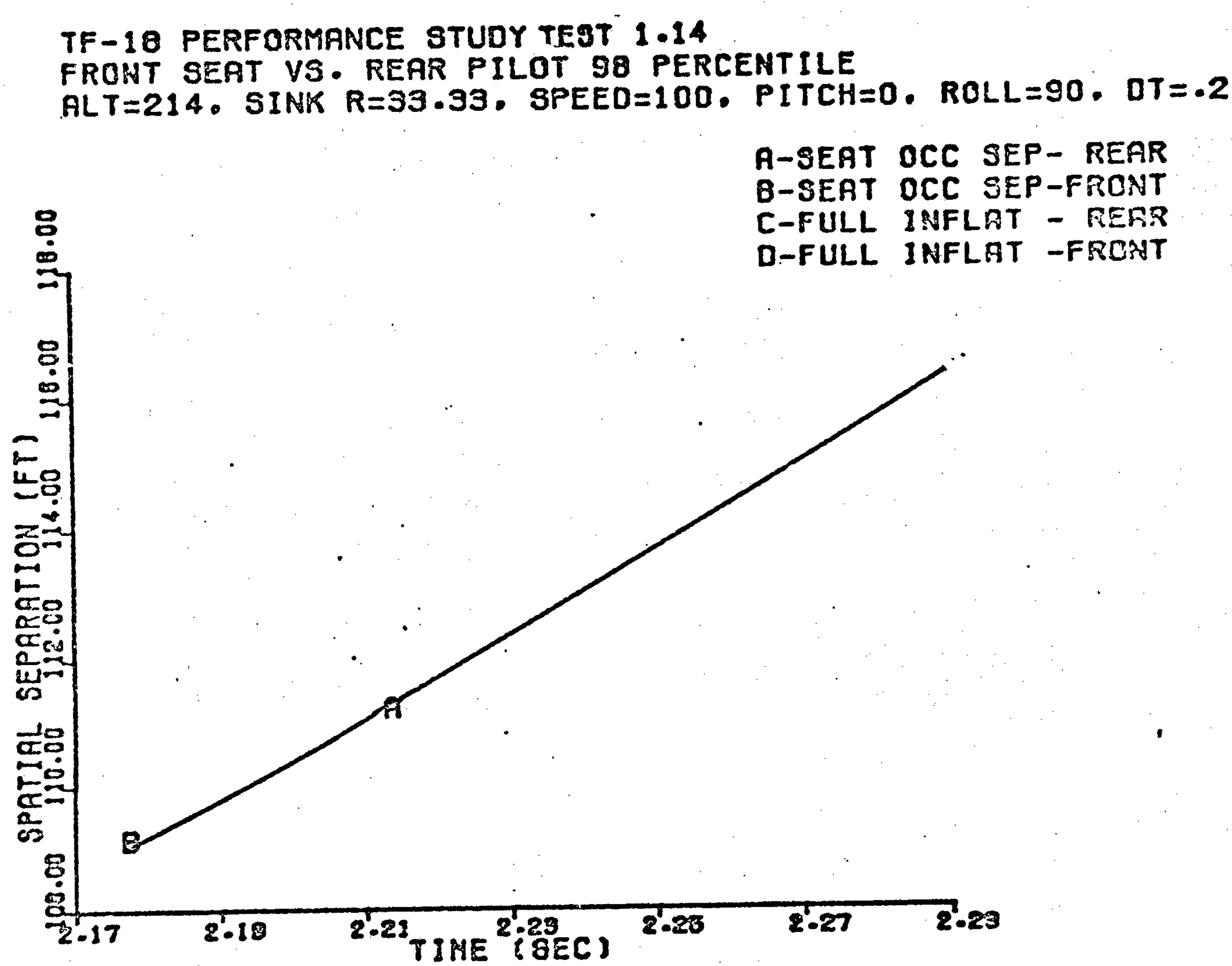

TF-18 PERFORMANCE STUDY TEST 1.14
FRONT SEAT VS. REAR PILOT 98 PERCENTILE
ALT=214. SINK R=33.33. SPEED=100. PITCH=0. ROLL=90. DT=.2
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
108.00
110.00
112.00
114.00
116.00
118.00
2.17
2.19
2.21
2.23
2.25
2.27
2.29
TIME (SEC)
A
B

Figure D-80

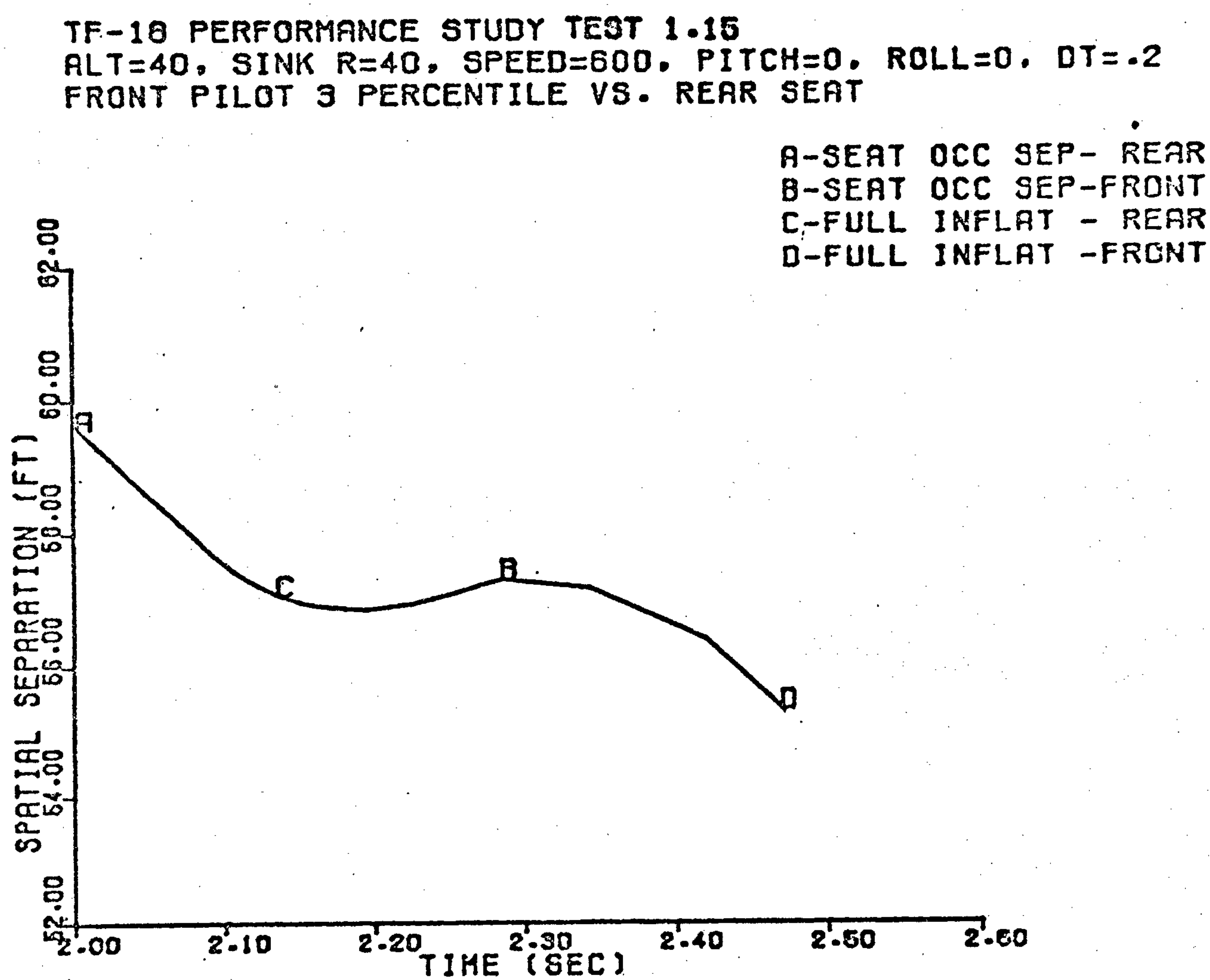

TF-18 PERFORMANCE STUDY TEST 1.15
ALT=40, SINK R=40, SPEED=600, PITCH=0, ROLL=0, DT=.2
FRONT PILOT 3 PERCENTILE VS. REAR SEAT
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
52.00
54.00
56.00
58.00
60.00
62.00
2.00
2.10
2.20
2.30
2.40
2.50
2.60
TIME (SEC)
A
B
C
D

Figure D-81

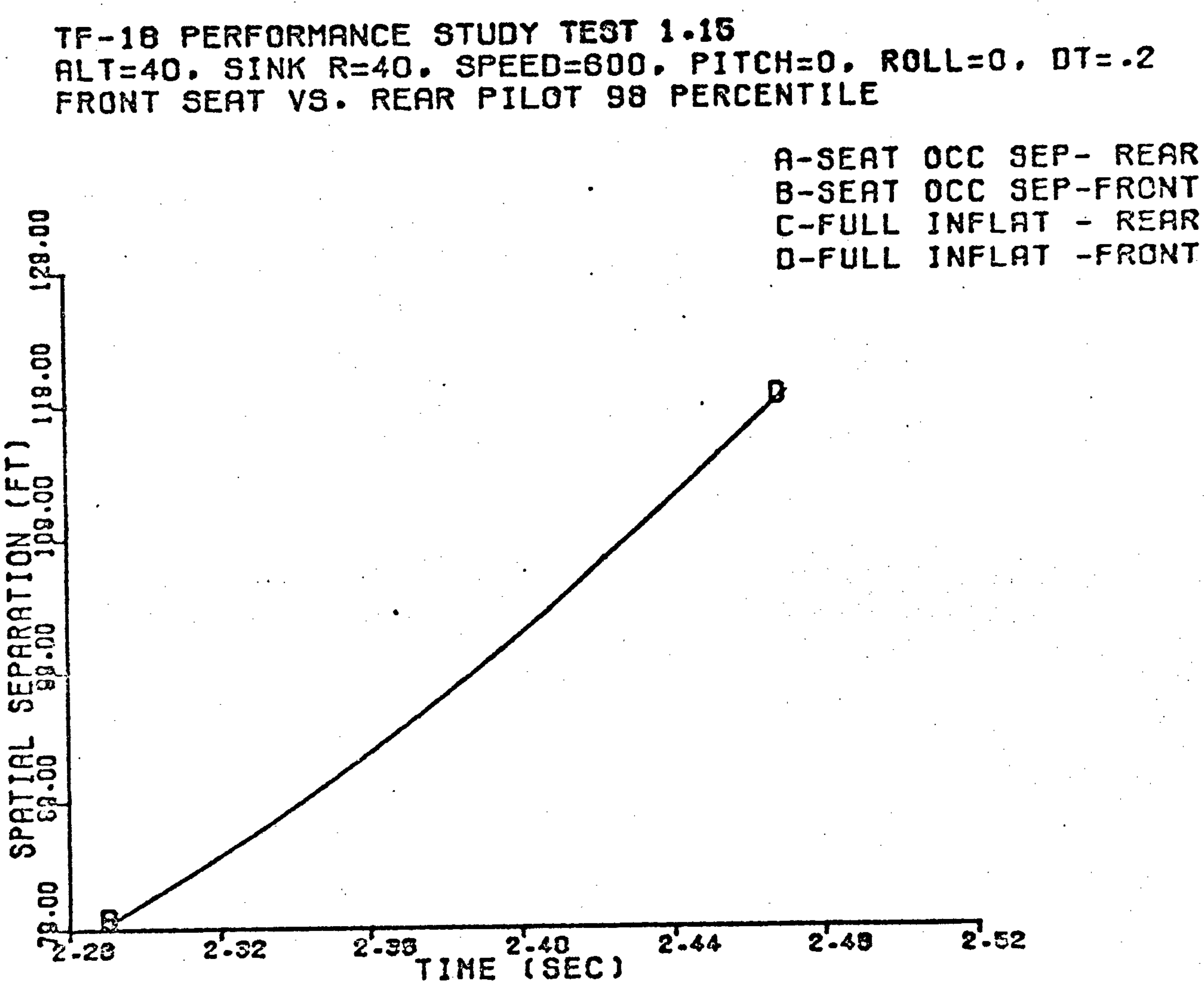
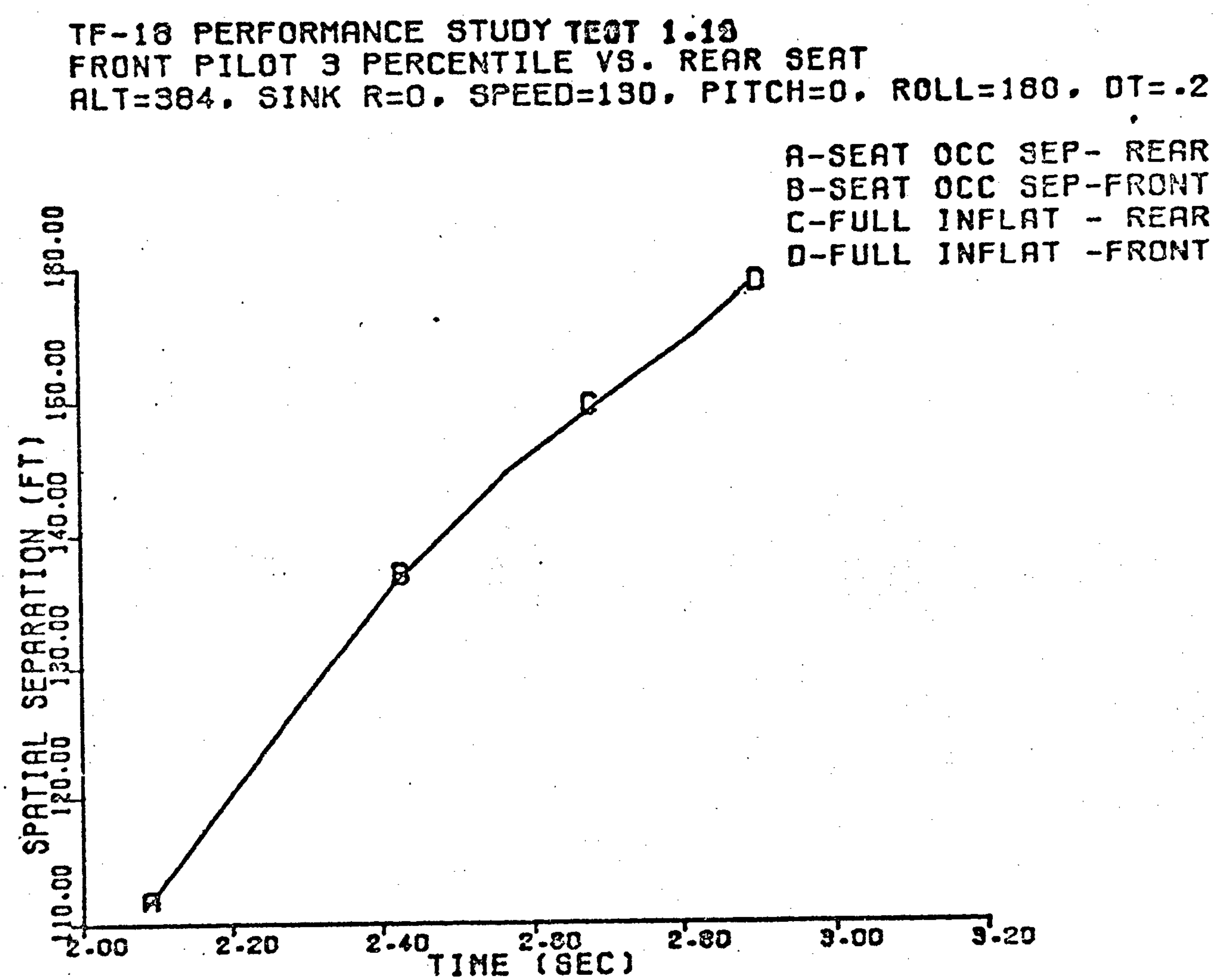

TF-18 PERFORMANCE STUDY TEST 1.15
ALT=40. SINK R=40. SPEED=600. PITCH=0. ROLL=0. DT=.2
FRONT SEAT VS. REAR PILOT 98 PERCENTILE
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
78.00
88.00
98.00
108.00
118.00
128.00
TIME (SEC)
2.28
2.32
2.36
2.40
2.44
2.48
2.52
B
D

Figure D-82



TF-18 PERFORMANCE STUDY TEST 1.18
FRONT PILOT 3 PERCENTILE VS. REAR SEAT
ALT=384. SINK R=0. SPEED=130. PITCH=0. ROLL=180. DT=.2
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
110.00
120.00
130.00
140.00
150.00
160.00
2.00
2.20
2.40
2.60
2.80
3.00
3.20
TIME (SEC)

Figure D-83

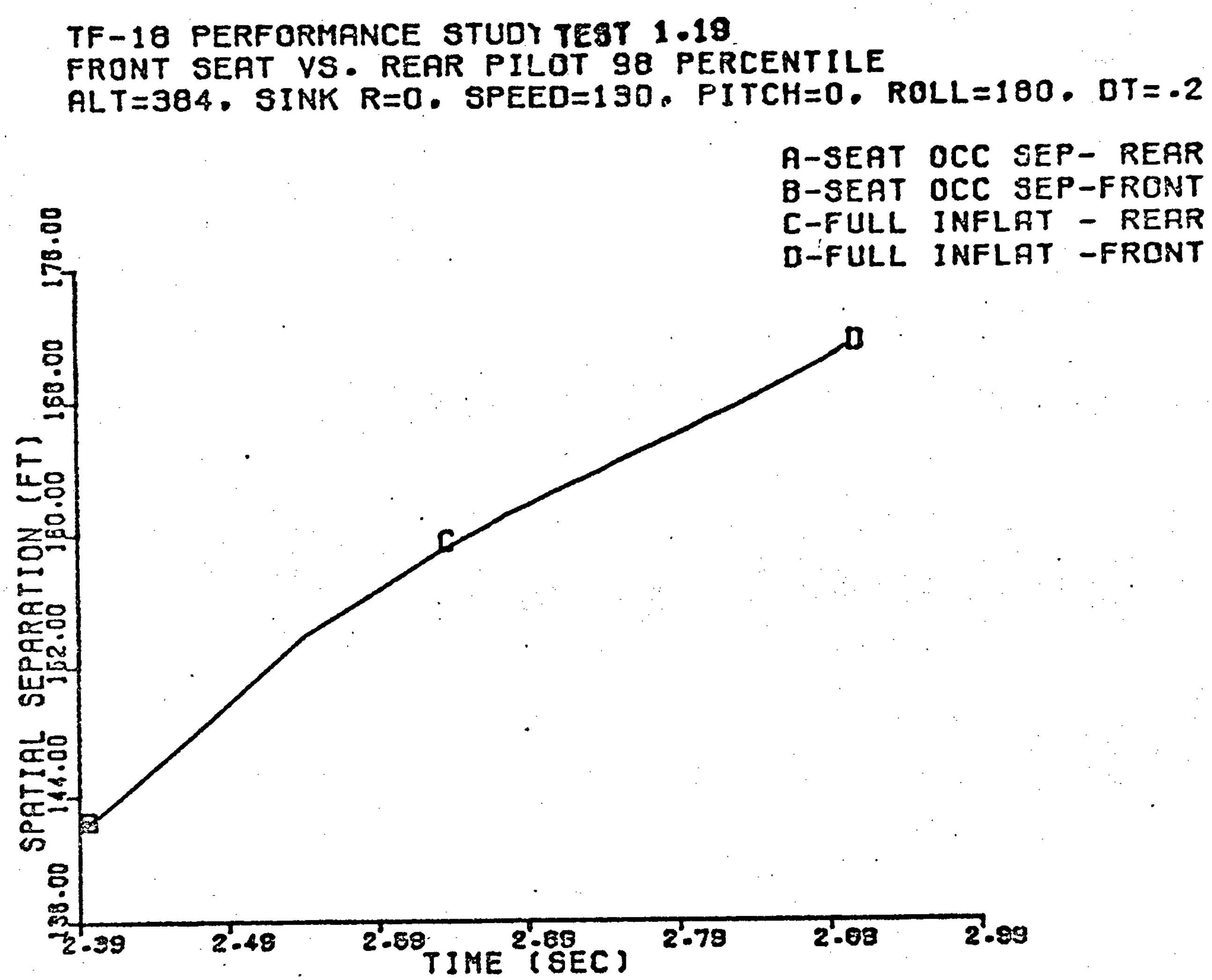

TF-18 PERFORMANCE STUDY TEST 1.19
FRONT SEAT VS. REAR PILOT 98 PERCENTILE
ALT=384. SINK R=0. SPEED=130. PITCH=0. ROLL=180. DT=.2
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
TIME (SEC)
2.39
2.49
2.59
2.69
2.79
2.89
2.99
136.00
144.00
152.00
160.00
168.00
176.00

Figure D-84

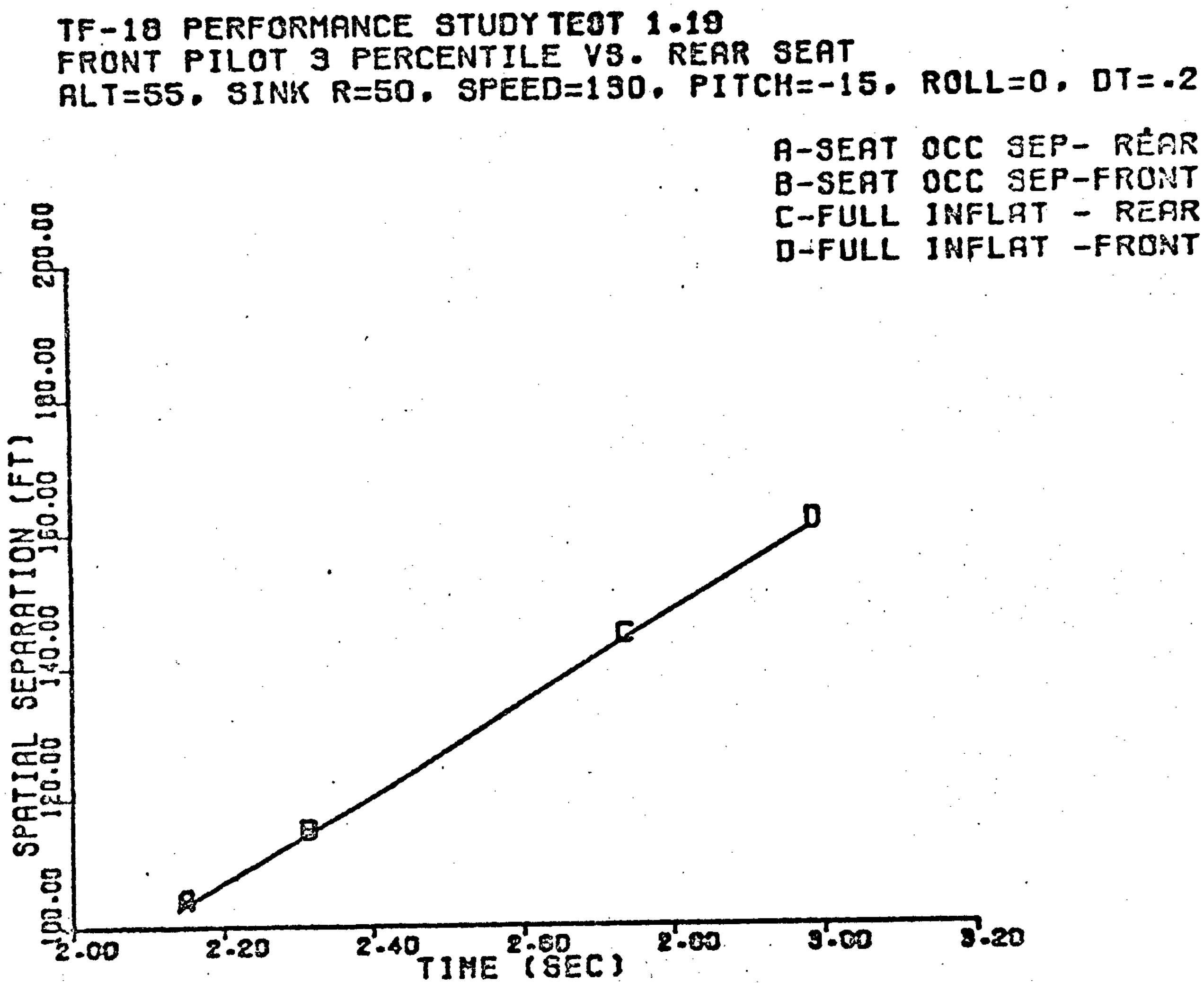

TF-18 PERFORMANCE STUDY TEST 1.19
FRONT PILOT 3 PERCENTILE VS. REAR SEAT
ALT=55. SINK R=50. SPEED=130. PITCH=-15. ROLL=0. DT=.2
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
200.00
180.00
160.00
140.00
120.00
100.00
2.00
2.20
2.40
2.60
2.80
3.00
3.20
TIME (SEC)
A
B
C
D

Figure D-85

TF-18 PERFORMANCE STUDY CASE 19
FRONT SEAT VS. REAR PILOT 98 PERCENTILE
ALT=55. SINK R=50. SPEED=130. PITCH=-15. ROLL=0. DT=.2

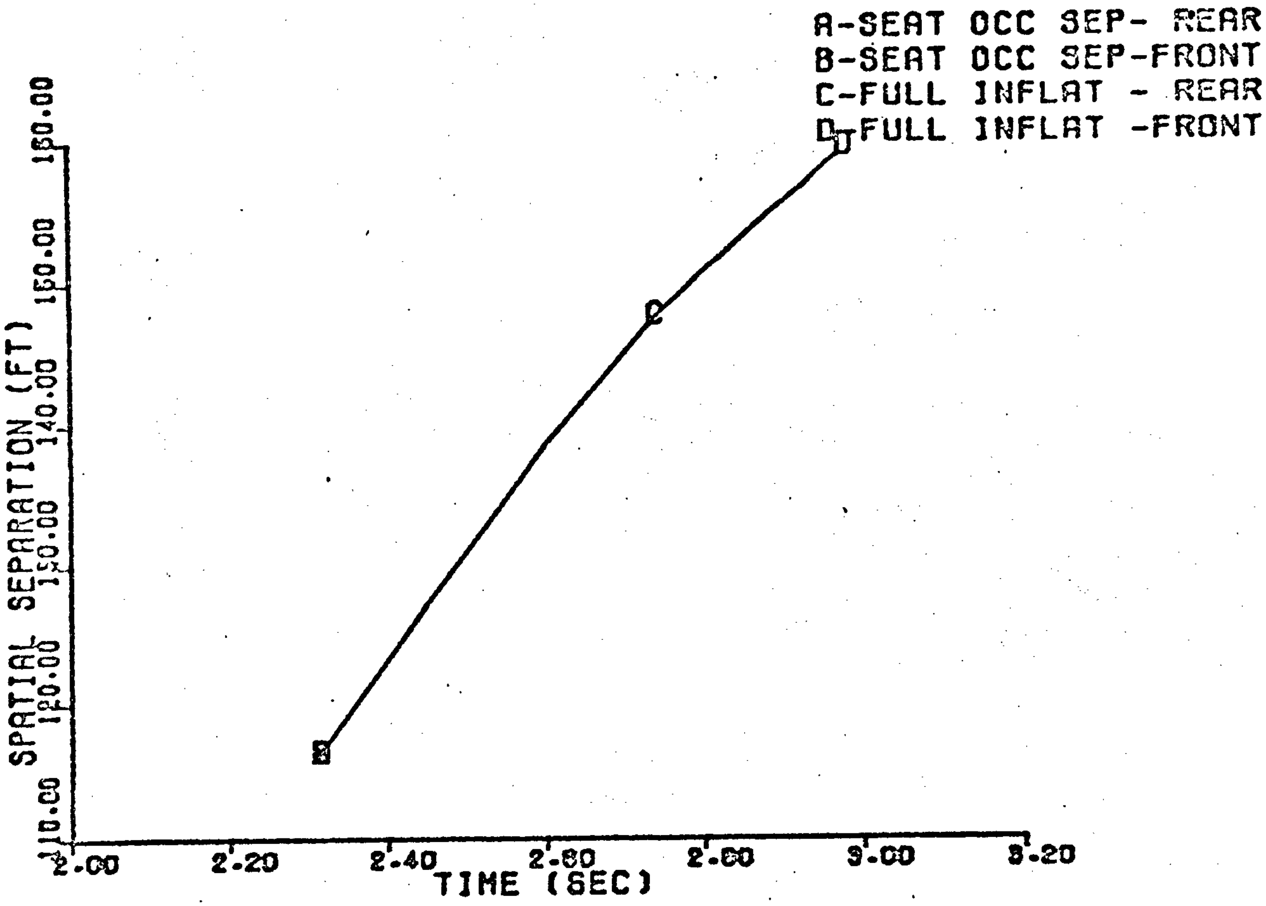


Figure D-86

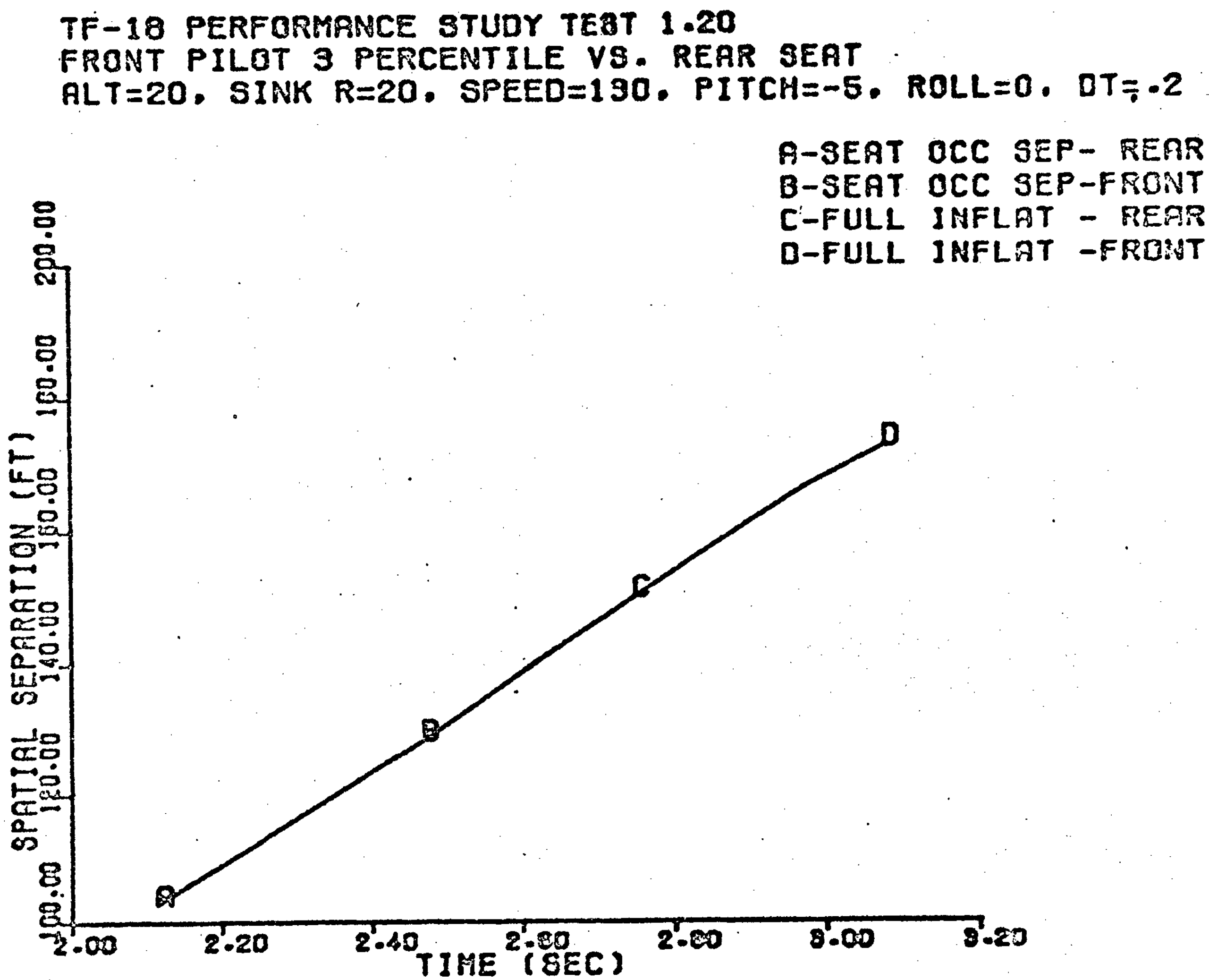

TF-18 PERFORMANCE STUDY TEST 1.20
FRONT PILOT 3 PERCENTILE VS. REAR SEAT
ALT=20, SINK R=20, SPEED=130, PITCH=-5, ROLL=0, DT=.2
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
100.00
120.00
140.00
160.00
180.00
200.00
2.00
2.20
2.40
2.60
2.80
3.00
3.20
TIME (SEC)

Figure D-87

TF-18 PERFORMANCE STUDY TEST 1.20
FRONT SEAT VS. REAR PILOT 98 PERCENTILE
ALT=20. SINK R=20. SPEED=130. PITCH=-5. ROLL=0. DT=.2

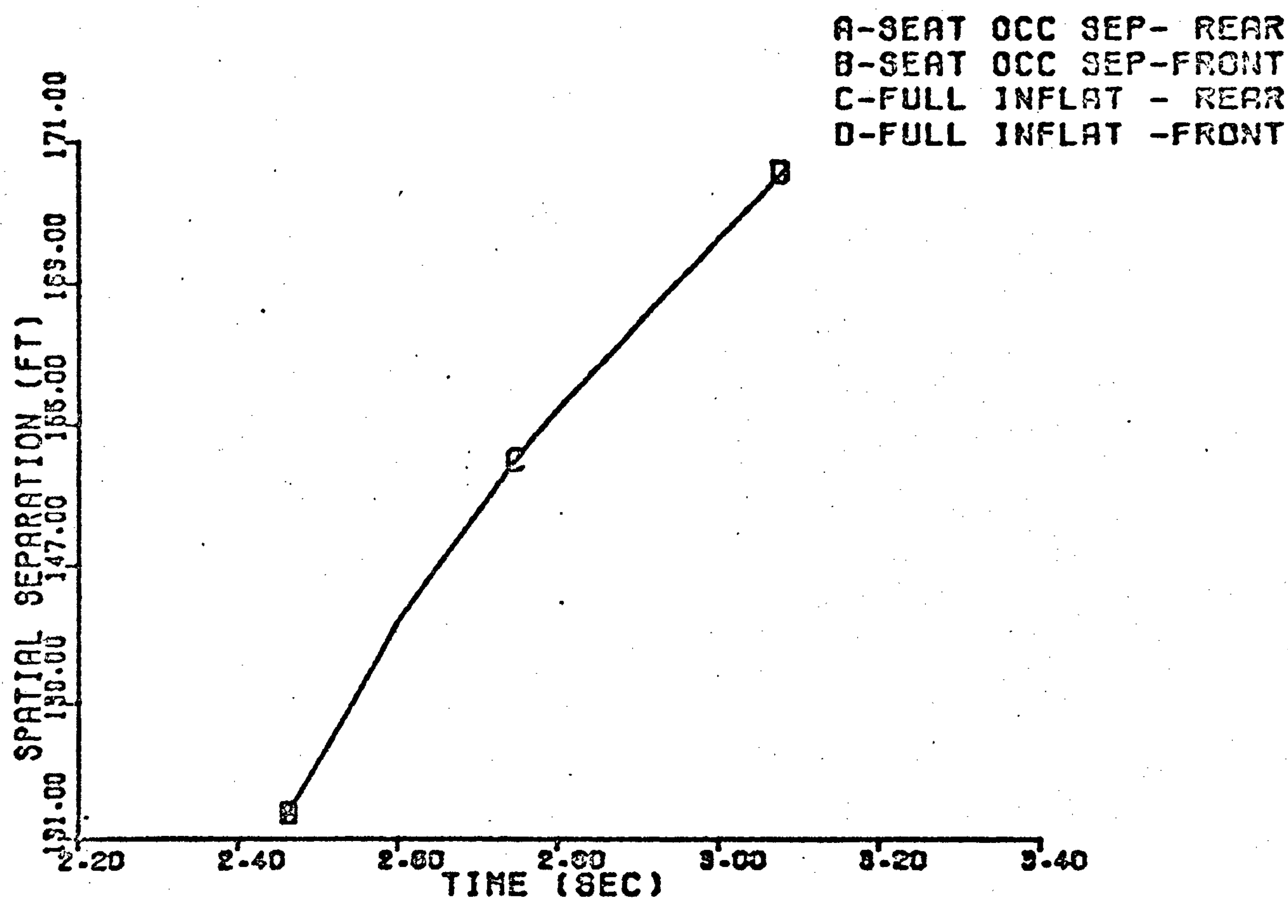


Figure D-88

TF-18 PERFORMANCE STUDY TEST 1.21
FRONT PILOT 98 PERCENTILE VS. REAR SEAT
ALT=0. SINK R=0. SPEED=0. PITCH=0. ROLL=0. DT=.4

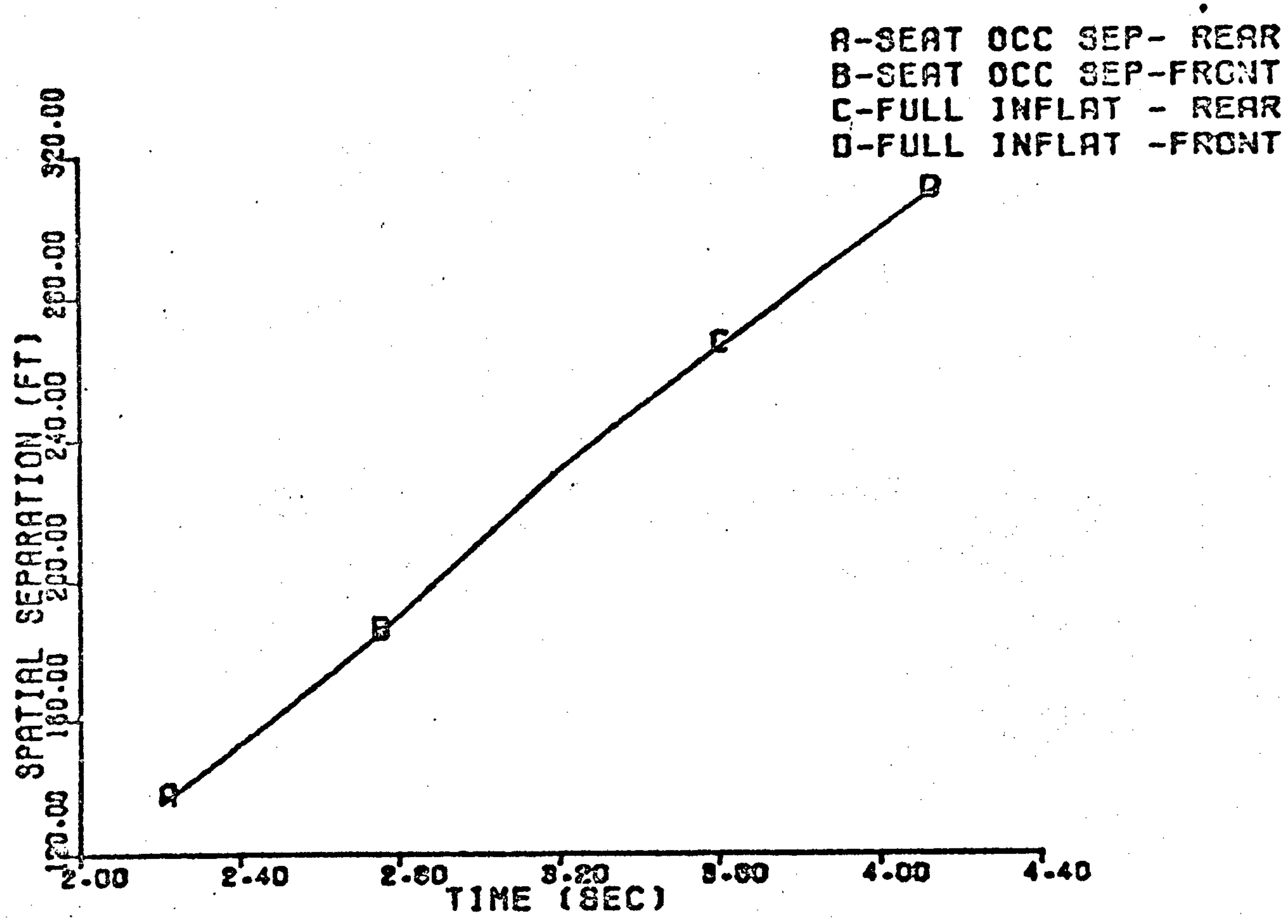


Figure D-89

TF-18 PERFORMANCE STUDY TEST 1.21
FRONT SEAT VS. REAR PILOT 3 PERCENTILE
ALT=0. SINK R=0. SPEED=0. PITCH=0. ROLL=0. DT=.4

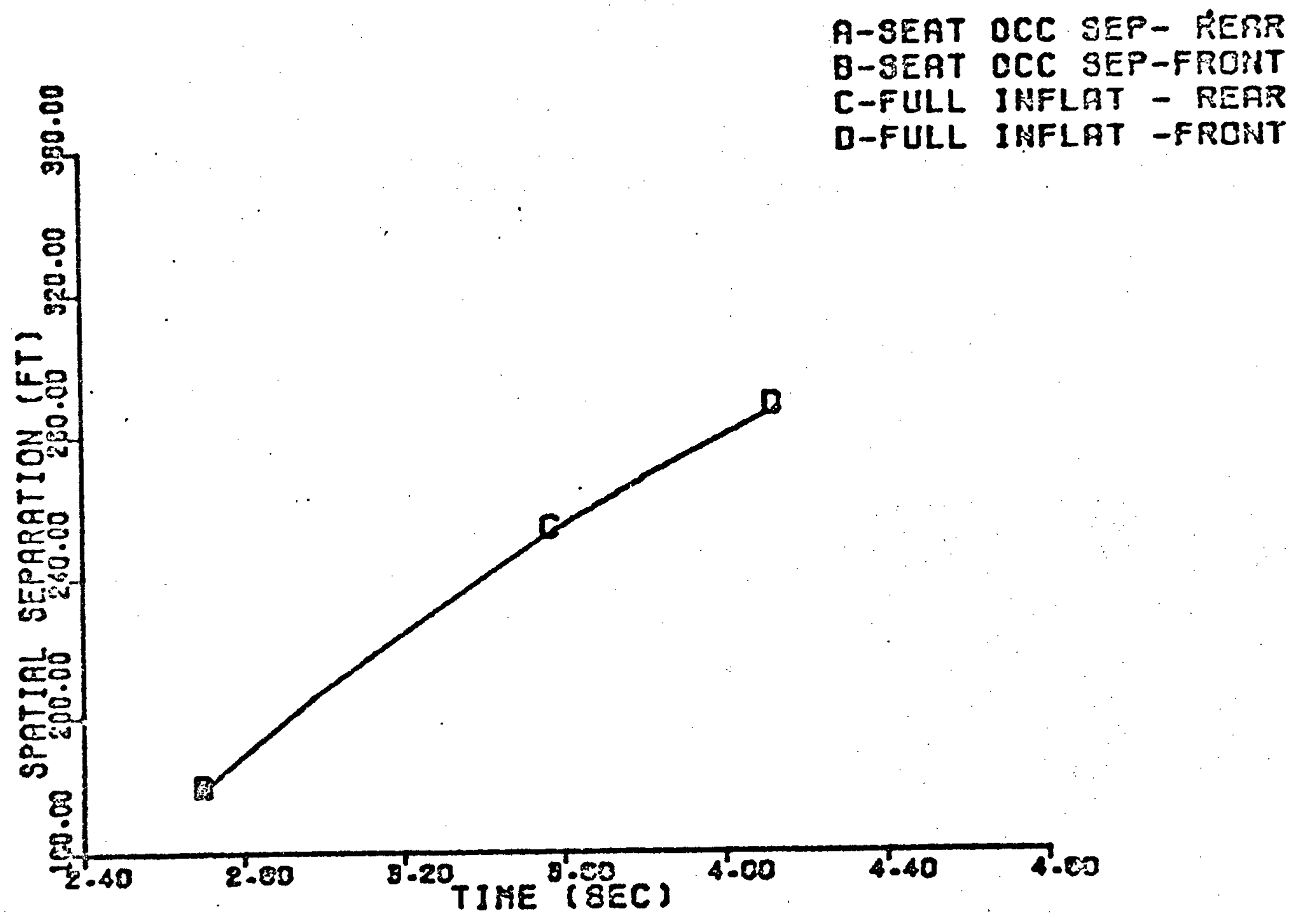


Figure D-90

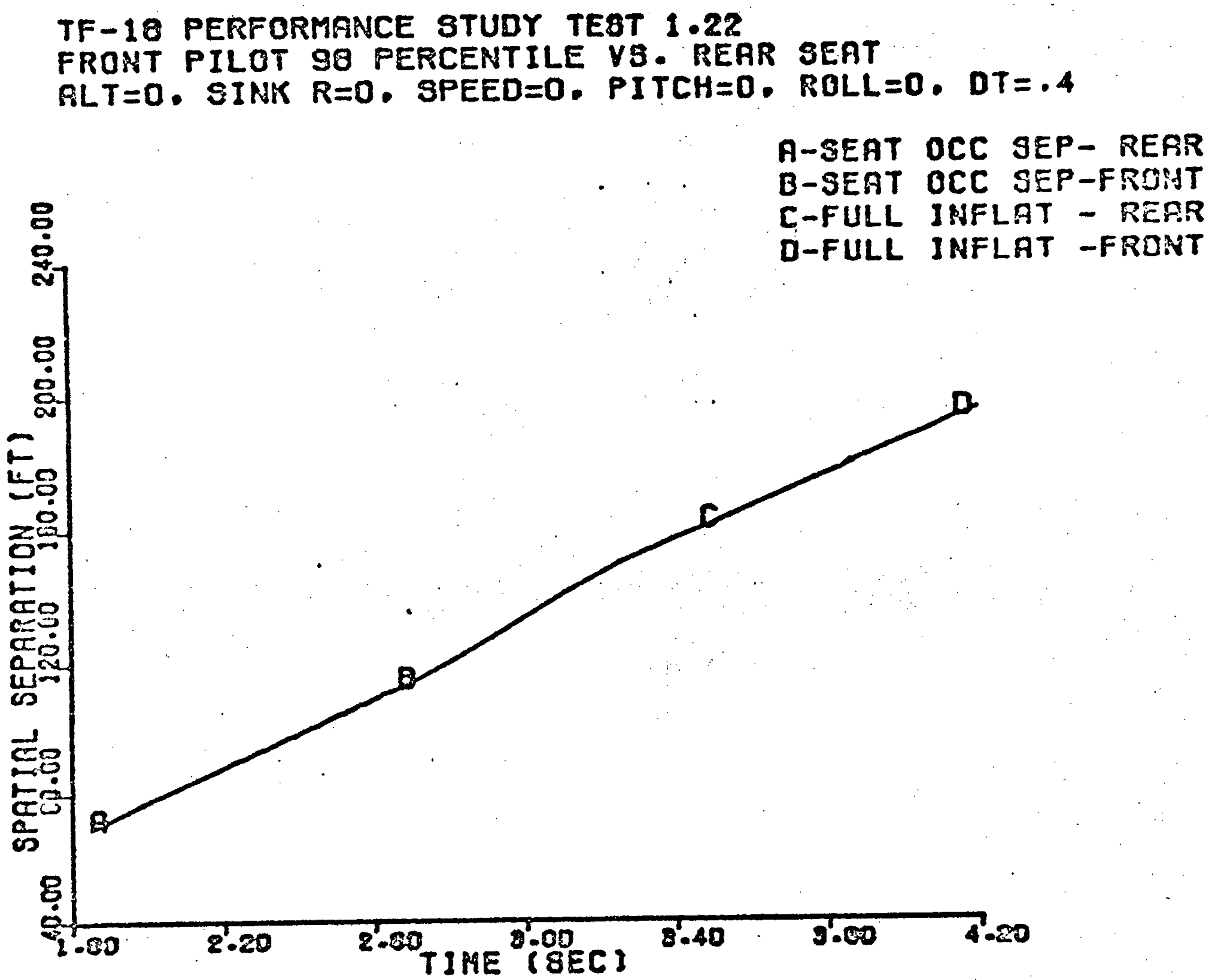

TF-18 PERFORMANCE STUDY TEST 1.22
FRONT PILOT 98 PERCENTILE VS. REAR SEAT
ALT=0. SINK R=0. SPEED=0. PITCH=0. ROLL=0. DT=.4
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
40.00
80.00
120.00
160.00
200.00
240.00
1.80
2.20
2.60
3.00
3.40
3.80
4.20
TIME (SEC)
A
B
C
D

Figure D-91

TF-18 PERFORMANCE STUDY TEST 1.22
FRONT SEAT VS. REAR PILOT 98 PERCENTILE
ALT=0. SINK R=0. SPEED=0. PITCH=0. ROLL=0. DT=.4

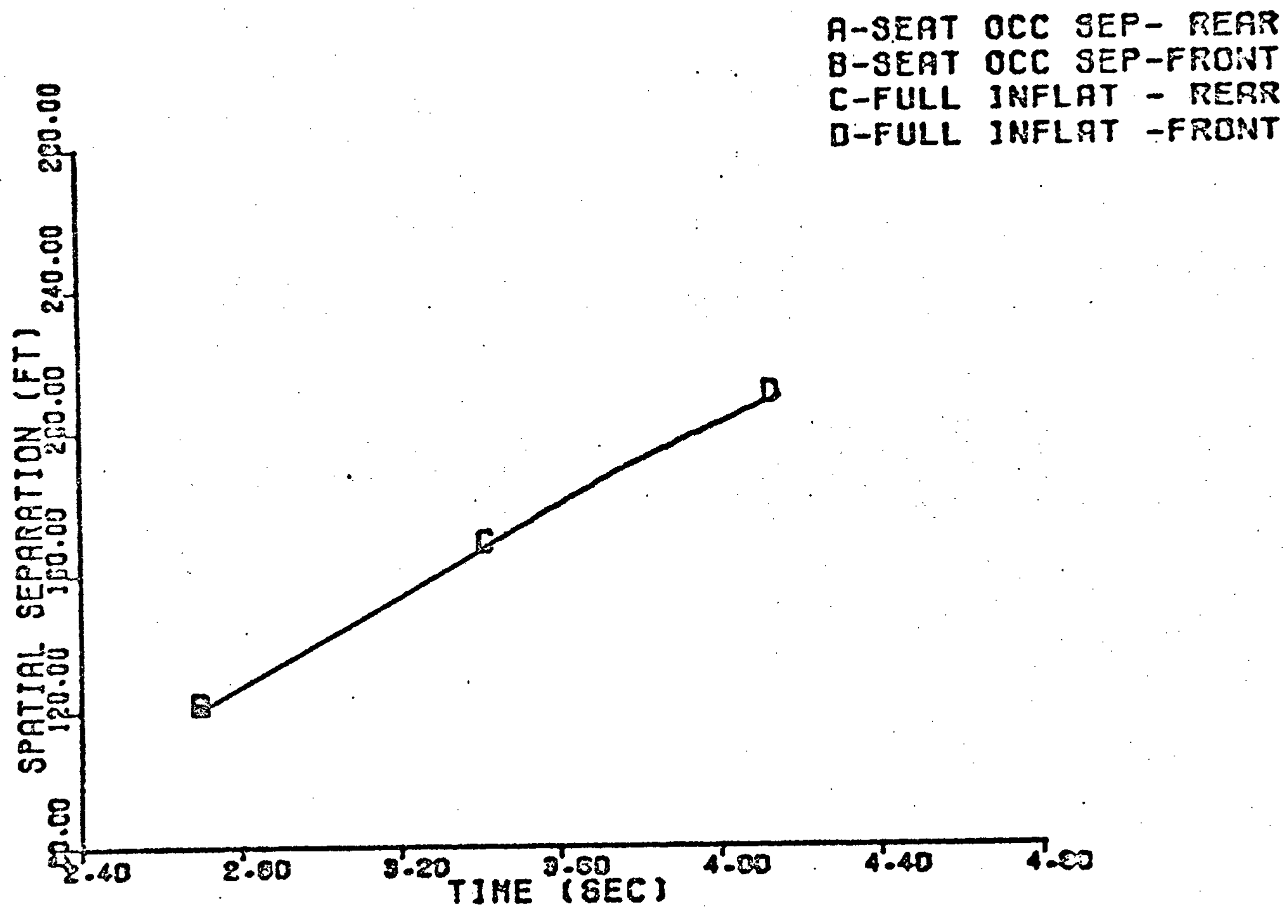


Figure D-92

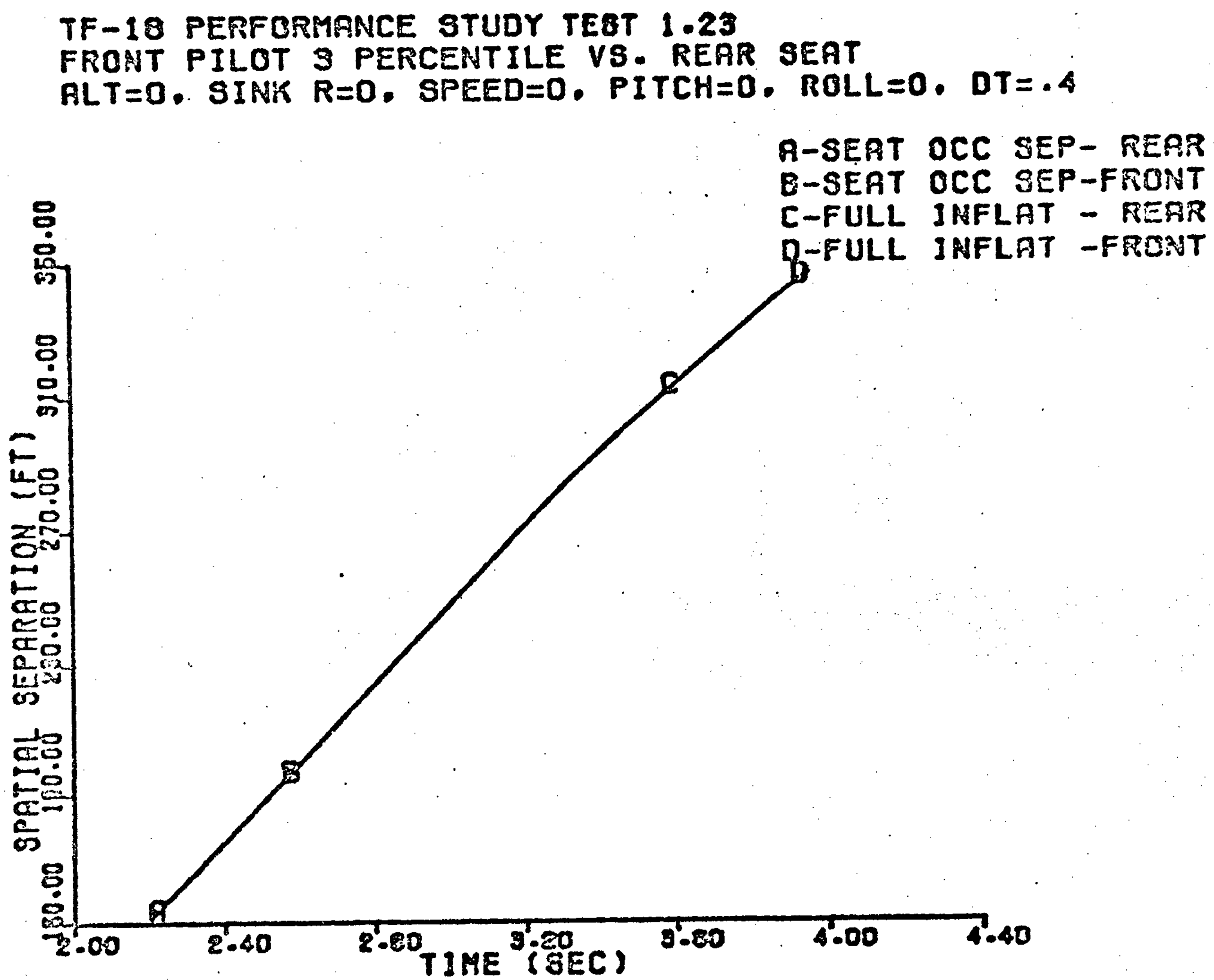

TF-18 PERFORMANCE STUDY TEST 1.23
FRONT PILOT 3 PERCENTILE VS. REAR SEAT
ALT=0. SINK R=0. SPEED=0. PITCH=0. ROLL=0. DT=.4
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
350.00
310.00
270.00
2.00
2.40
2.80
3.20
3.60
4.00
4.40
TIME (SEC)

Figure D-93

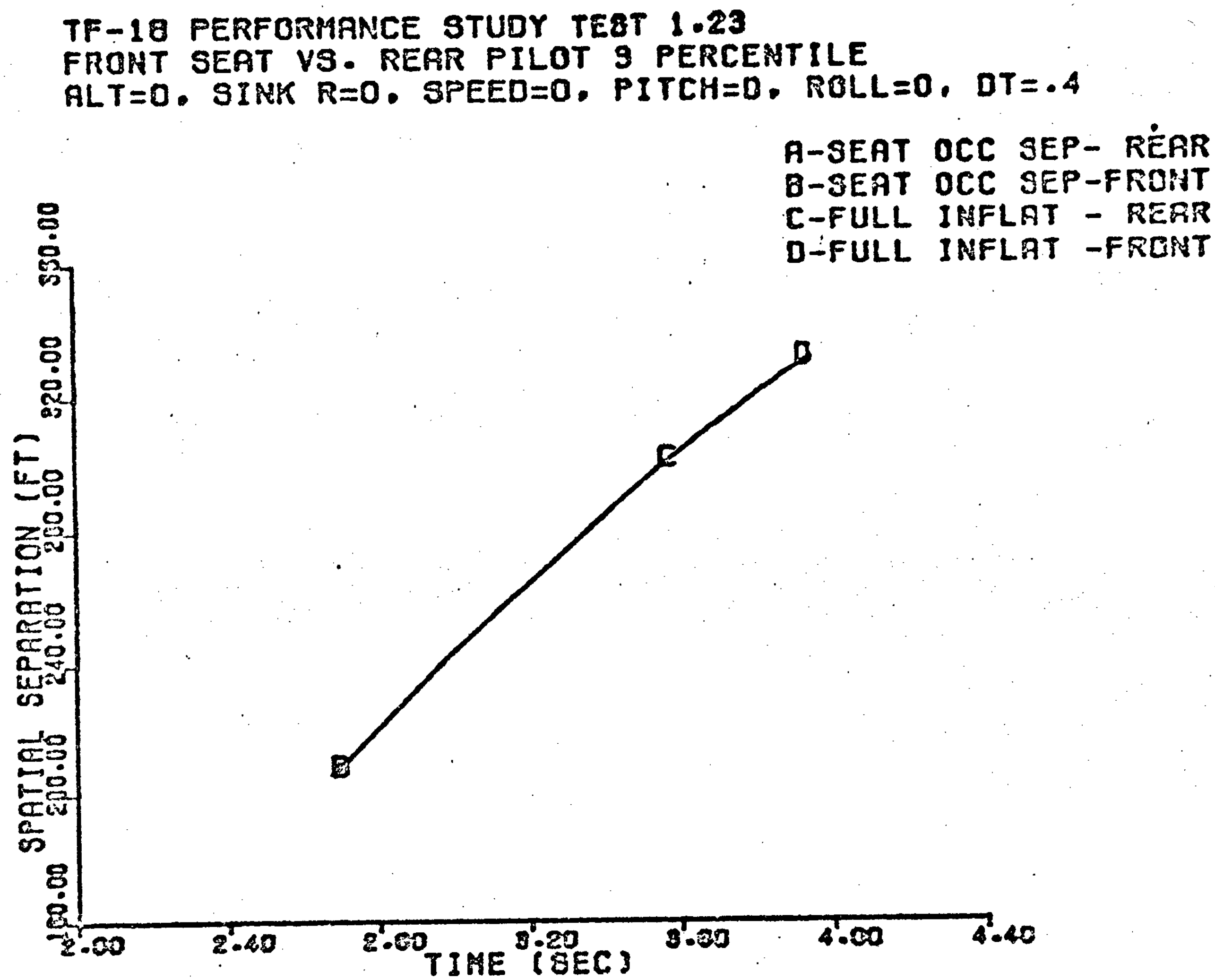

TF-18 PERFORMANCE STUDY TEST 1.23
FRONT SEAT VS. REAR PILOT 3 PERCENTILE
ALT=0. SINK R=0. SPEED=0. PITCH=0. ROLL=0. DT=.4
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
TIME (SEC)
2.00
2.40
4.00
4.40

Figure D-94

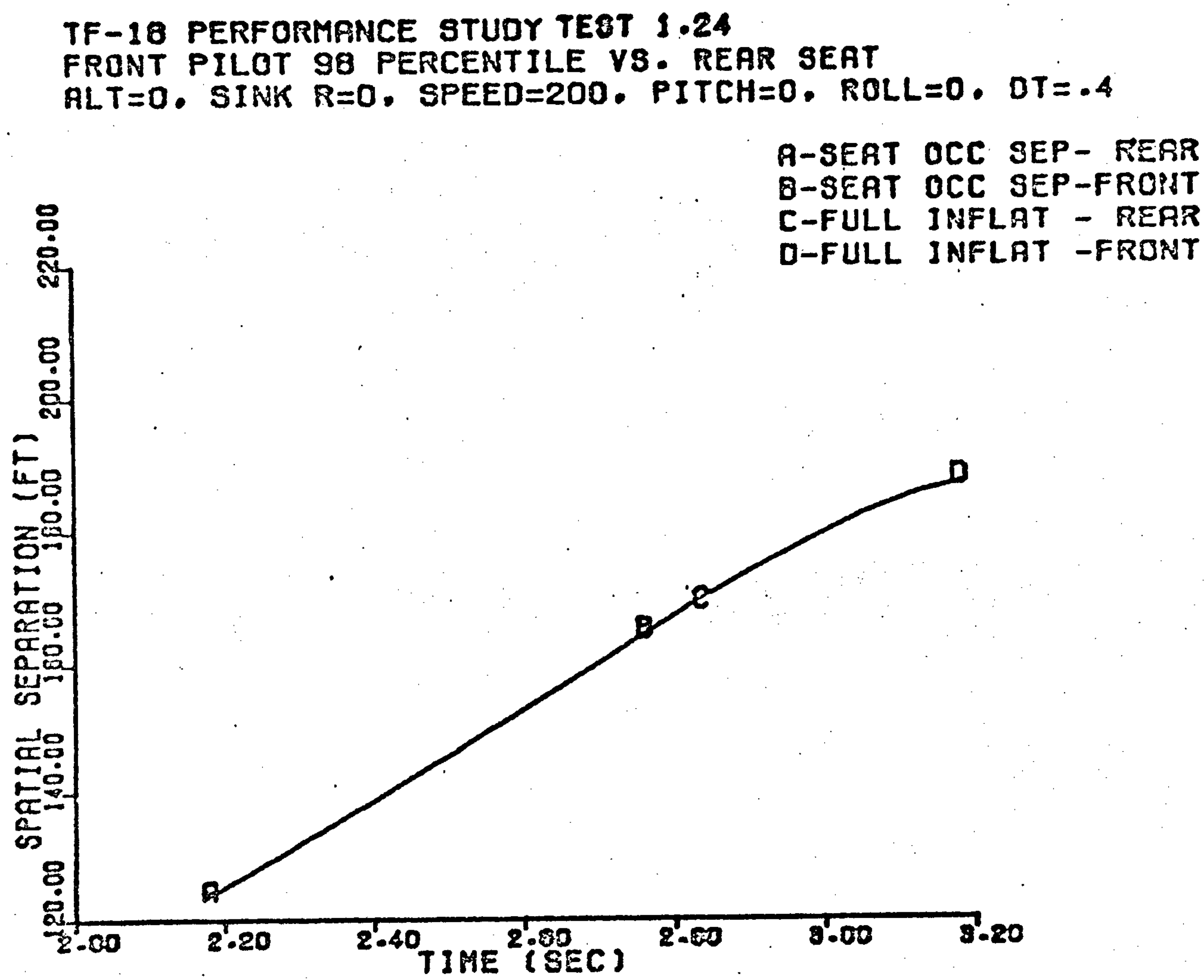

TF-18 PERFORMANCE STUDY TEST 1.24
FRONT PILOT 98 PERCENTILE VS. REAR SEAT
ALT=0. SINK R=0. SPEED=200. PITCH=0. ROLL=0. DT=.4
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
120.00
140.00
160.00
180.00
200.00
220.00
TIME (SEC)
2.00
2.20
2.40
2.60
2.80
3.00
3.20
A
B
C
D

Figure D-95

TF-18 PERFORMANCE STUDY TEST 1.24
FRONT SEAT VS. REAR PILOT 3 PERCENTILE
ALT=0. SINK R=0. SPEED=200. PITCH=0. ROLL=0. DT=.4

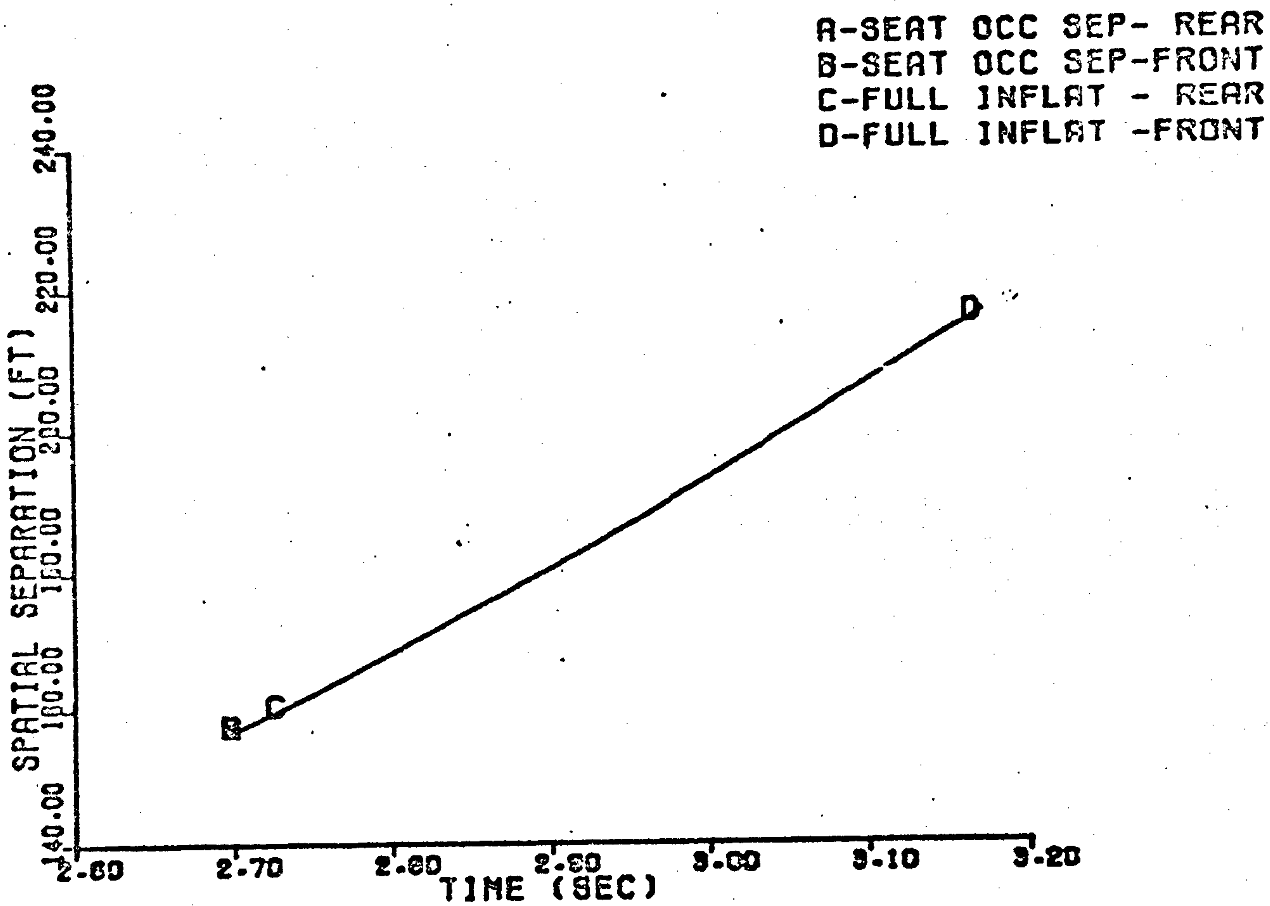


Figure D-96

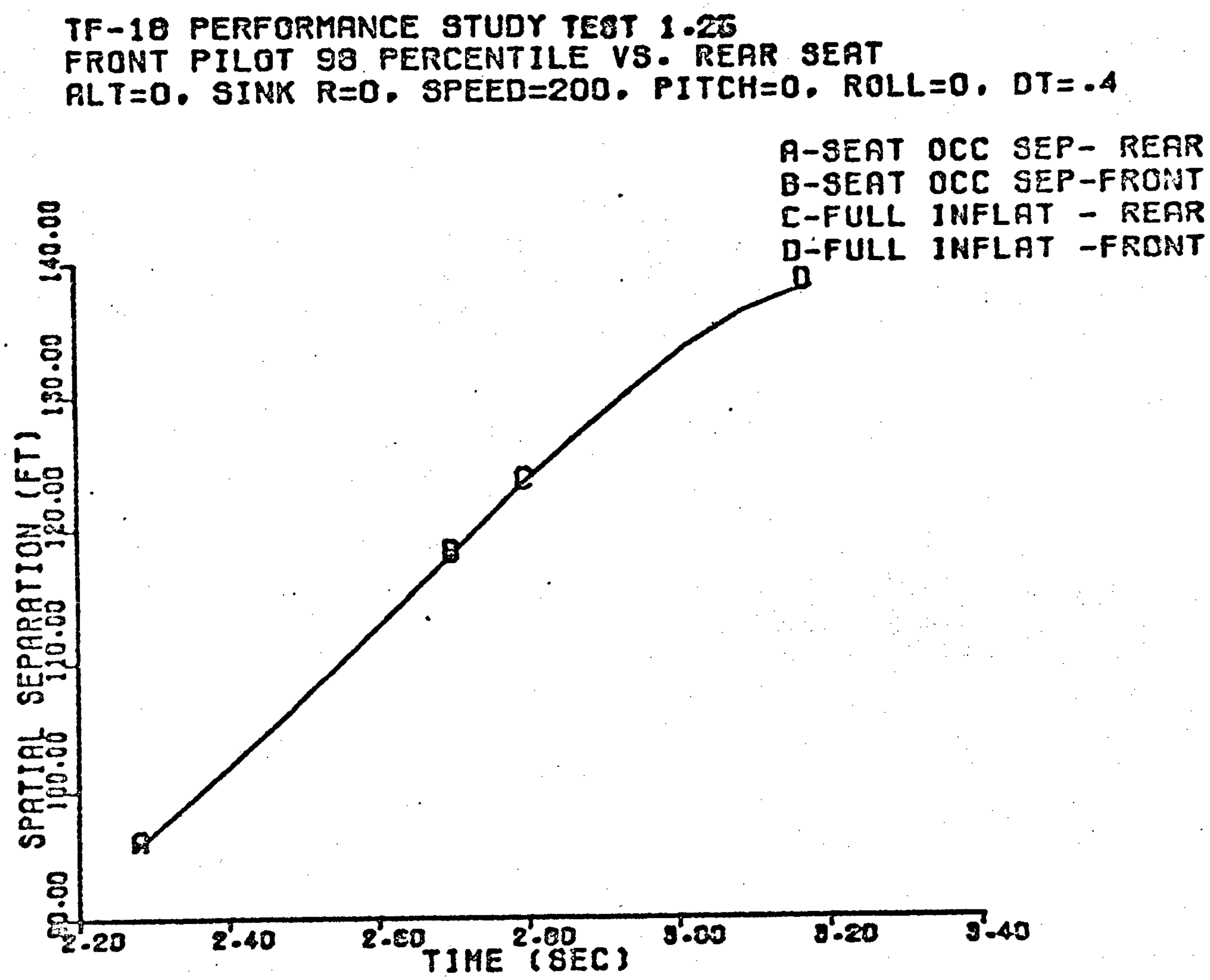

TF-18 PERFORMANCE STUDY TEST 1.25
FRONT PILOT 98 PERCENTILE VS. REAR SEAT
ALT=0. SINK R=0. SPEED=200. PITCH=0. ROLL=0. DT=.4
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
TIME (SEC)
2.20
2.40
2.60
2.80
3.00
3.20
3.40
100.00
110.00
120.00
130.00
140.00

Figure D-97

TF-18 PERFORMANCE STUDY TEST 1.25
FRONT SEAT VS. REAR PILOT 98 PERCENTILE
ALT=0. SINK R=0. SPEED=200. PITCH=0. ROLL=0. DT=.4

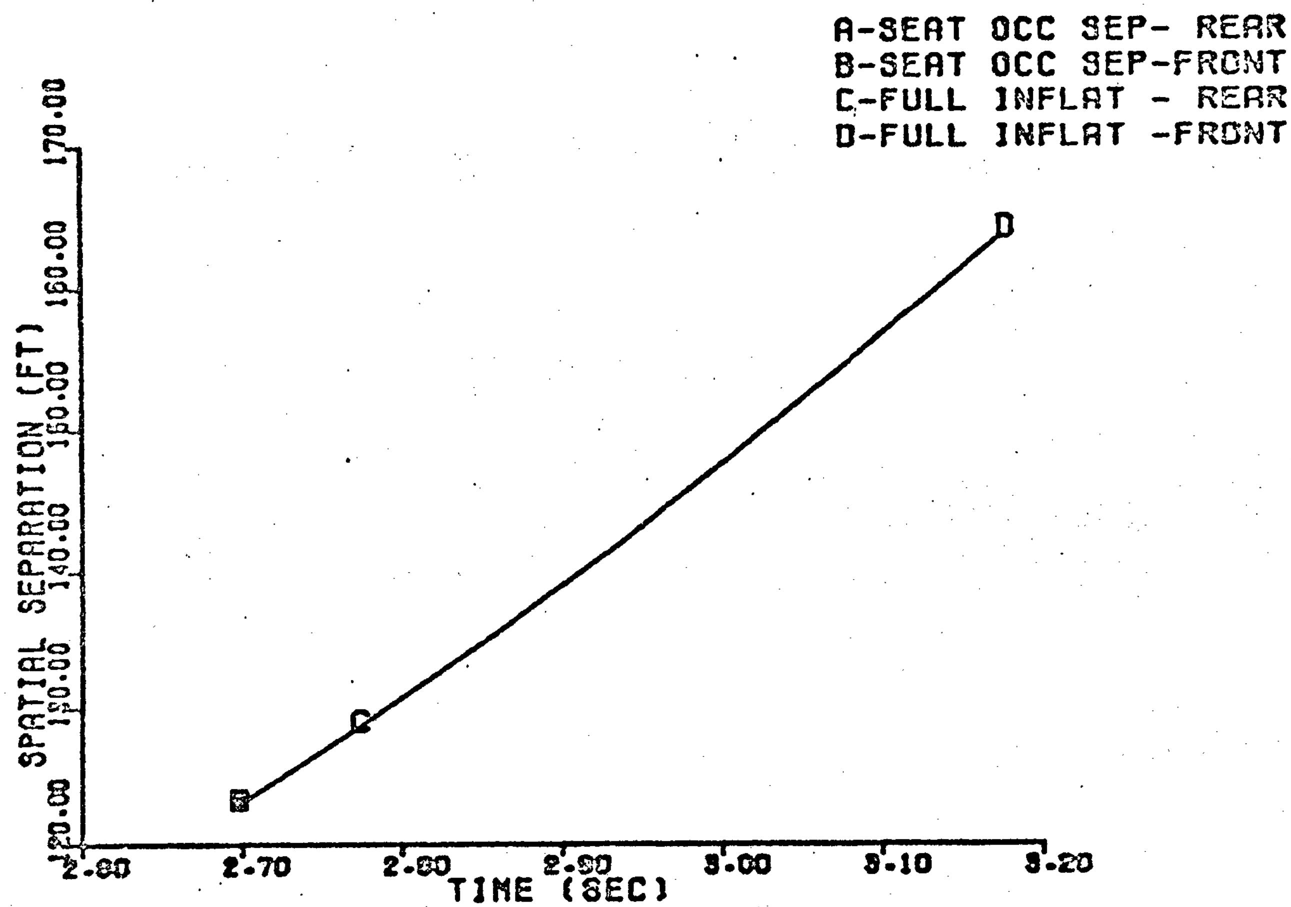


Figure D-98

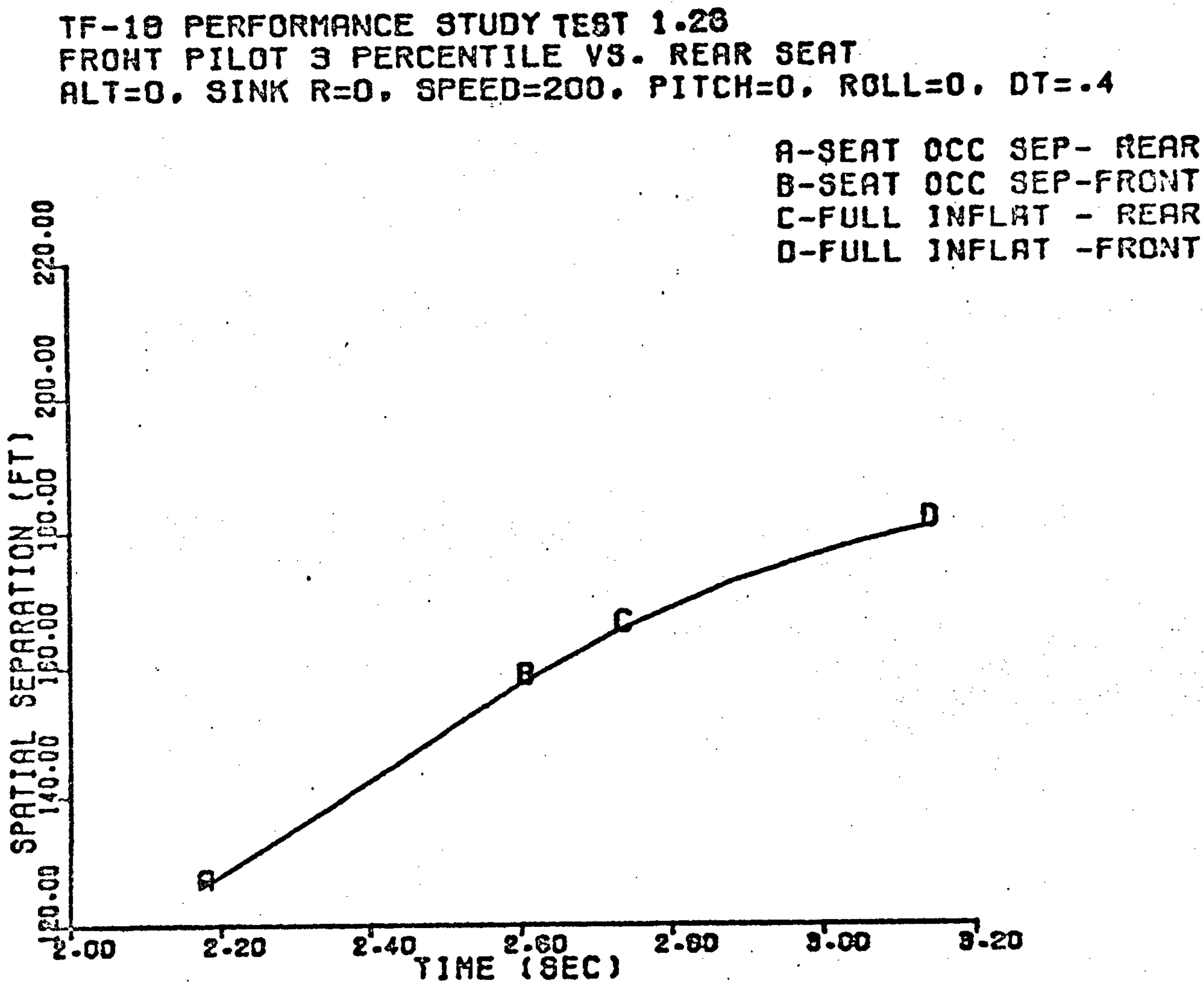

TF-18 PERFORMANCE STUDY TEST 1.28
FRONT PILOT 3 PERCENTILE VS. REAR SEAT
ALT=0. SINK R=0. SPEED=200. PITCH=0. ROLL=0. DT=.4
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
120.00
140.00
160.00
180.00
200.00
220.00
TIME (SEC)
2.00
2.20
2.40
2.60
2.80
3.00
3.20
A
B
C
D

Figure D-99

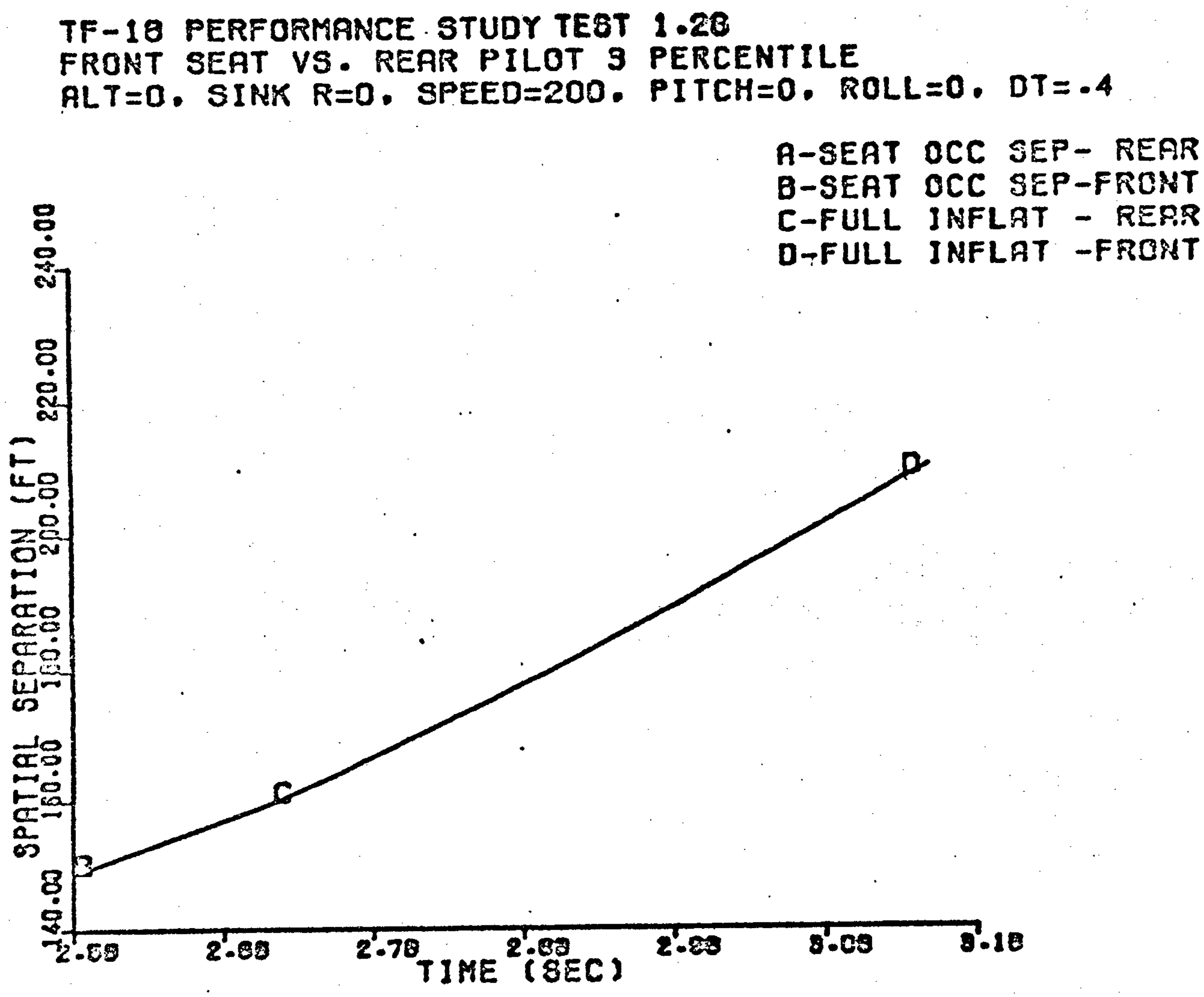

TF-18 PERFORMANCE STUDY TEST 1.28
FRONT SEAT VS. REAR PILOT 3 PERCENTILE
ALT=0. SINK R=0. SPEED=200. PITCH=0. ROLL=0. DT=.4
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
140.00
220.00
240.00
TIME (SEC)
2.70

Figure D-100

TF-18 PERFORMANCE STUDY TEST 1.27
FRONT PILOT 98 PERCENTILE VS. REAR SEAT
ALT=0, SINK R=0, SPEED=500, PITCH=0, ROLL=0, DT=.4

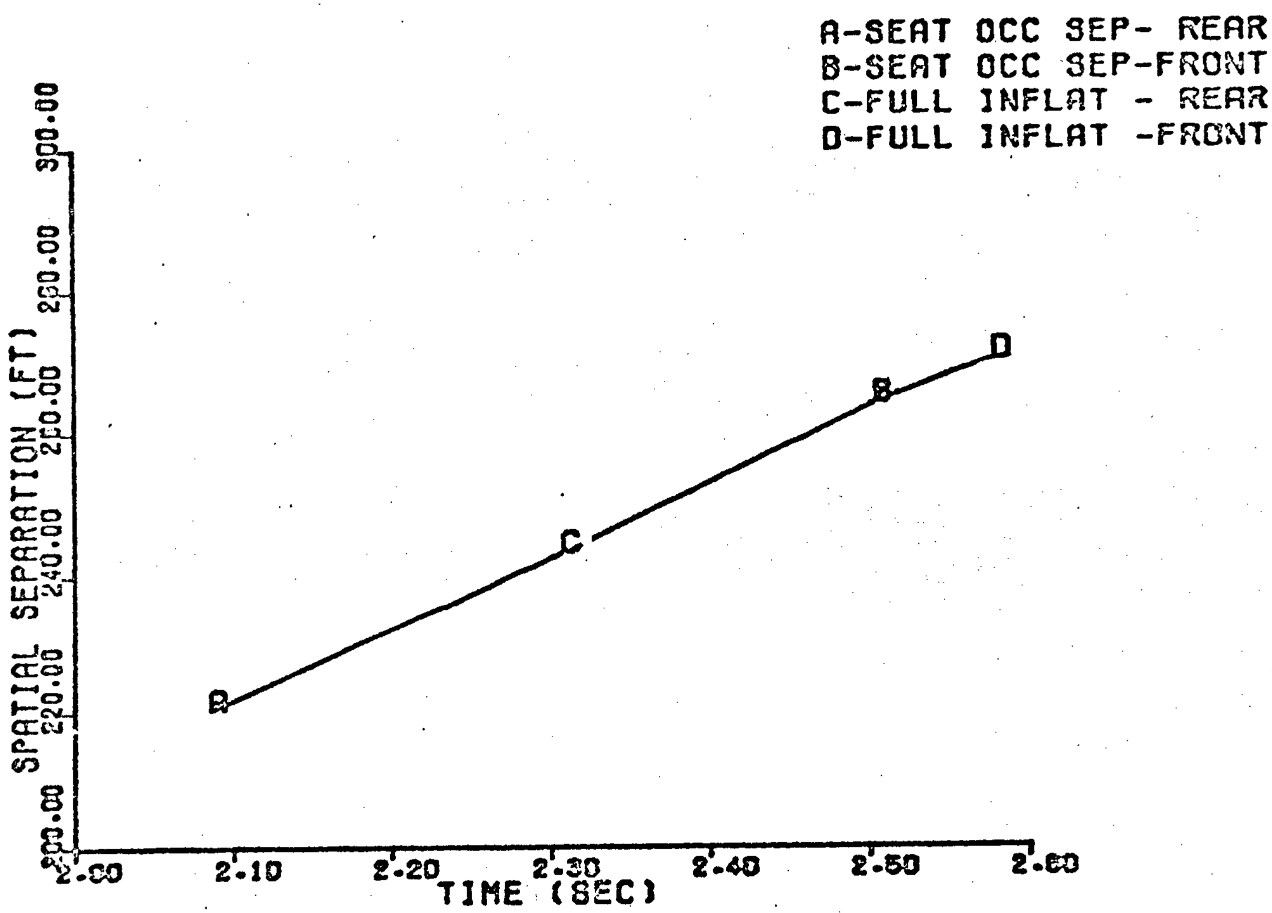


Figure D-101

TF-18 PERFORMANCE STUDY TEST 1.27
FRONT SEAT VS. REAR PILOT 3 PERCENTILE
ALT=0. SINK R=0. SPEED=500. PITCH=0. ROLL=0. DT=.4

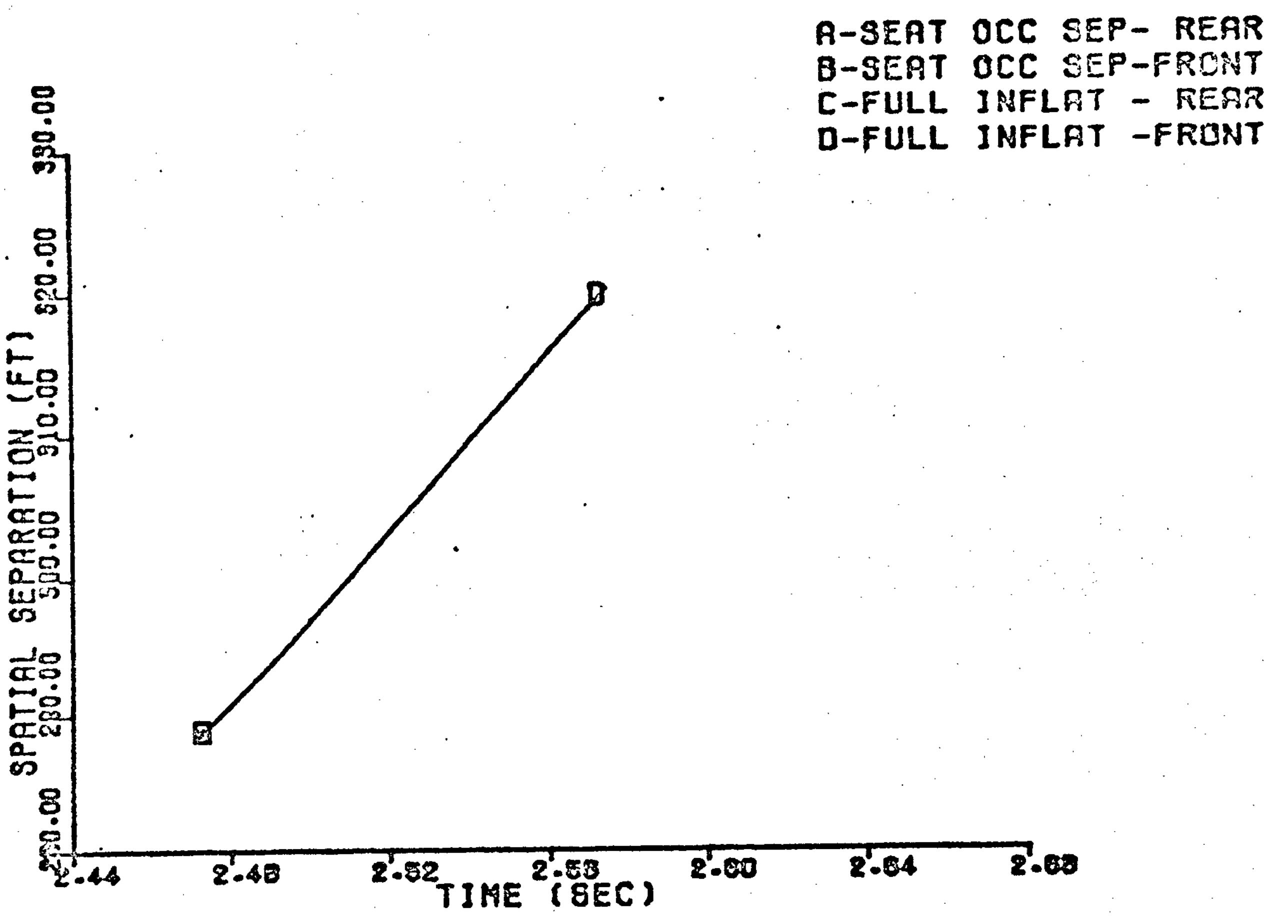


Figure D-102

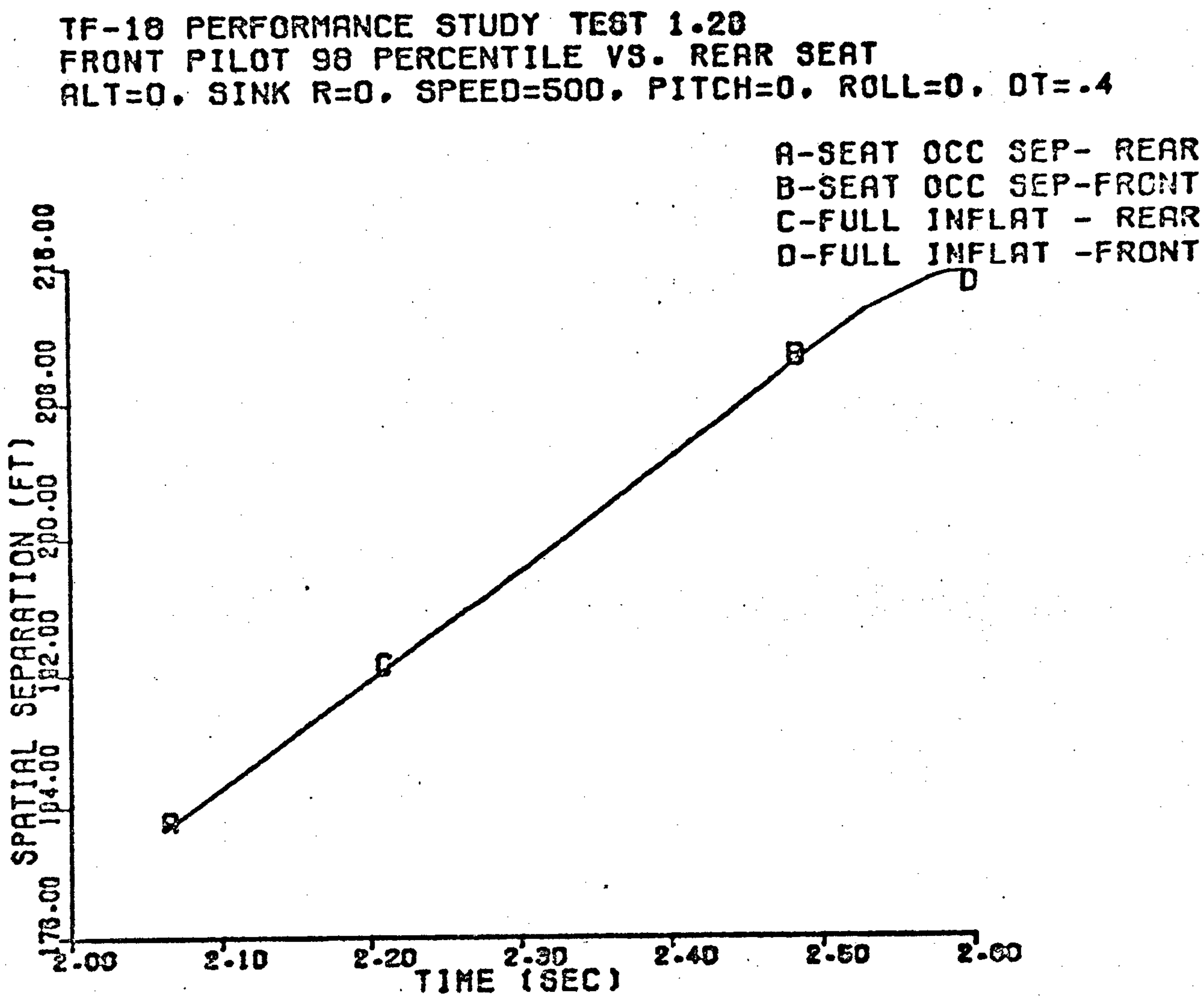

TF-18 PERFORMANCE STUDY TEST 1.28
FRONT PILOT 98 PERCENTILE VS. REAR SEAT
ALT=0. SINK R=0. SPEED=500. PITCH=0. ROLL=0. DT=.4
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
TIME (SEC)
2.00
2.10
2.20
2.30
2.40
2.50
2.60
176.00
184.00
192.00
200.00
208.00
216.00

Figure D-103

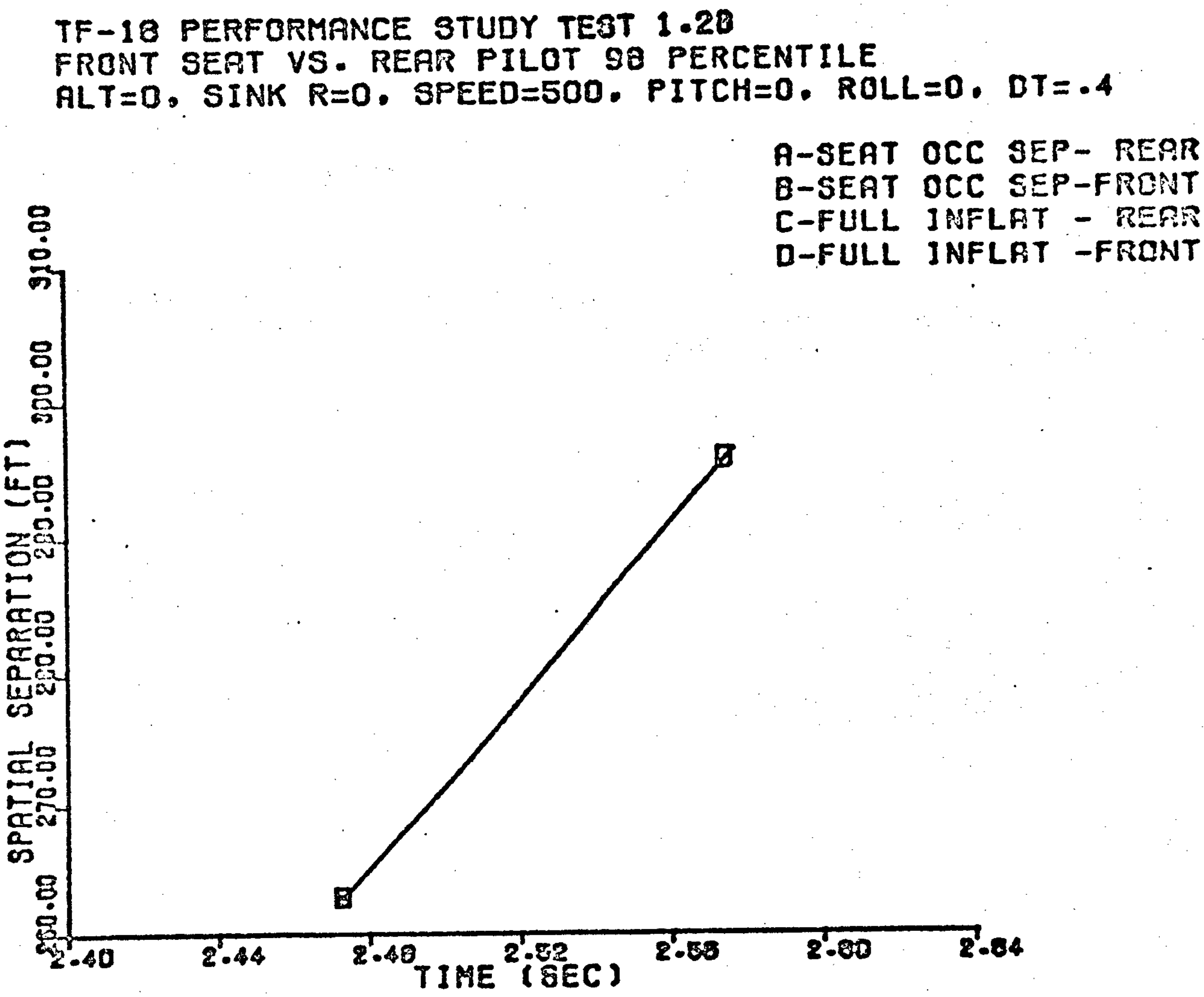

TF-18 PERFORMANCE STUDY TEST 1.20
FRONT SEAT VS. REAR PILOT 98 PERCENTILE
ALT=0. SINK R=0. SPEED=500. PITCH=0. ROLL=0. DT=.4
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
270.00
280.00
290.00
300.00
310.00
2.40
2.44
2.48
2.52
2.56
2.60
2.64
TIME (SEC)

Figure D-104

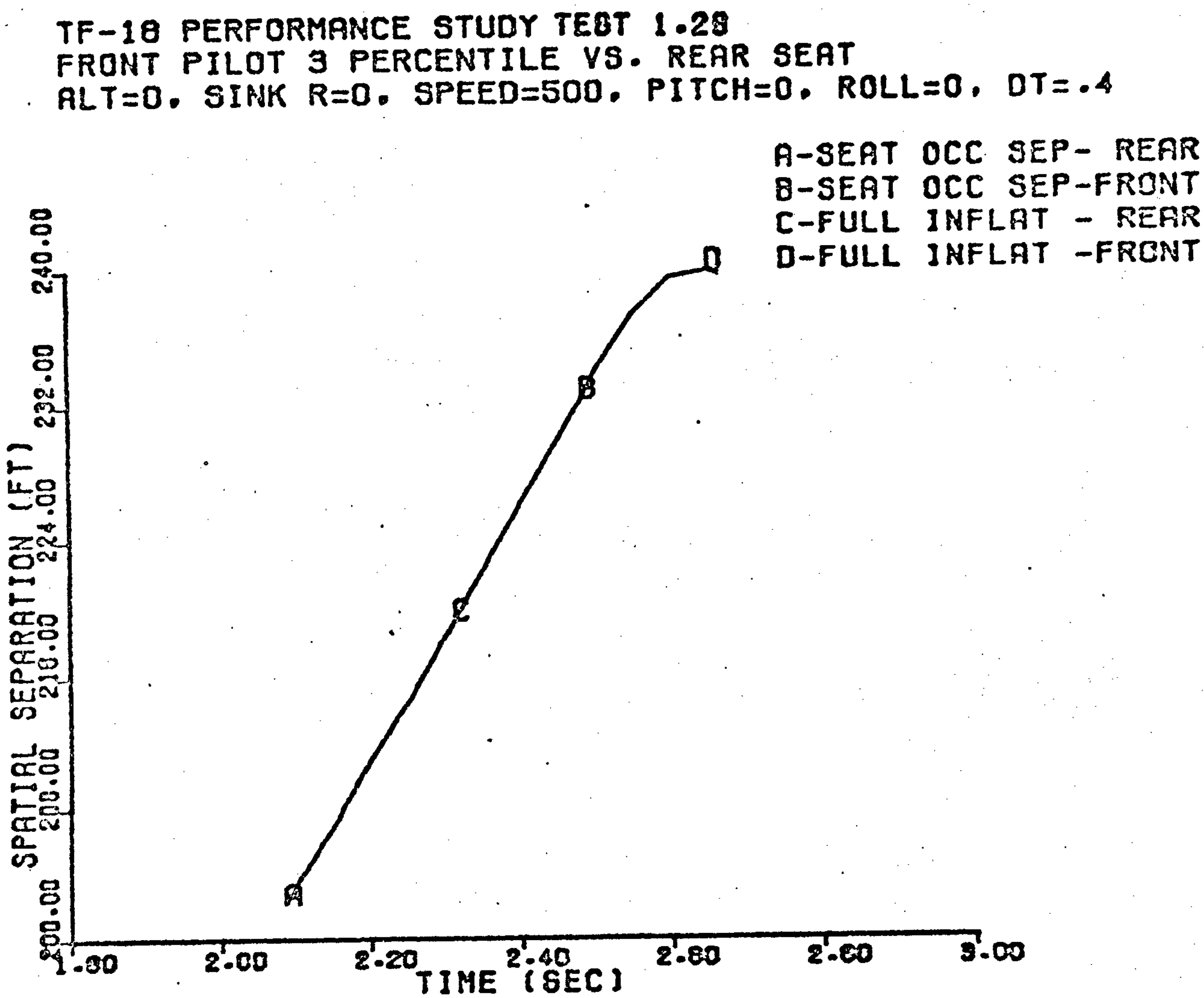

TF-18 PERFORMANCE STUDY TEST 1.28
FRONT PILOT 3 PERCENTILE VS. REAR SEAT
ALT=0. SINK R=0. SPEED=500. PITCH=0. ROLL=0. DT=.4
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
240.00
232.00
224.00
200.00
TIME (SEC)
1.80
2.00
2.20
2.40
3.00

Figure D-105

TF-18 PERFORMANCE STUDY TEST 1.28
FRONT SEAT VS. REAR PILOT 3 PERCENTILE
ALT=0. SINK R=0. SPEED=500. PITCH=0. ROLL=0. DT=.4

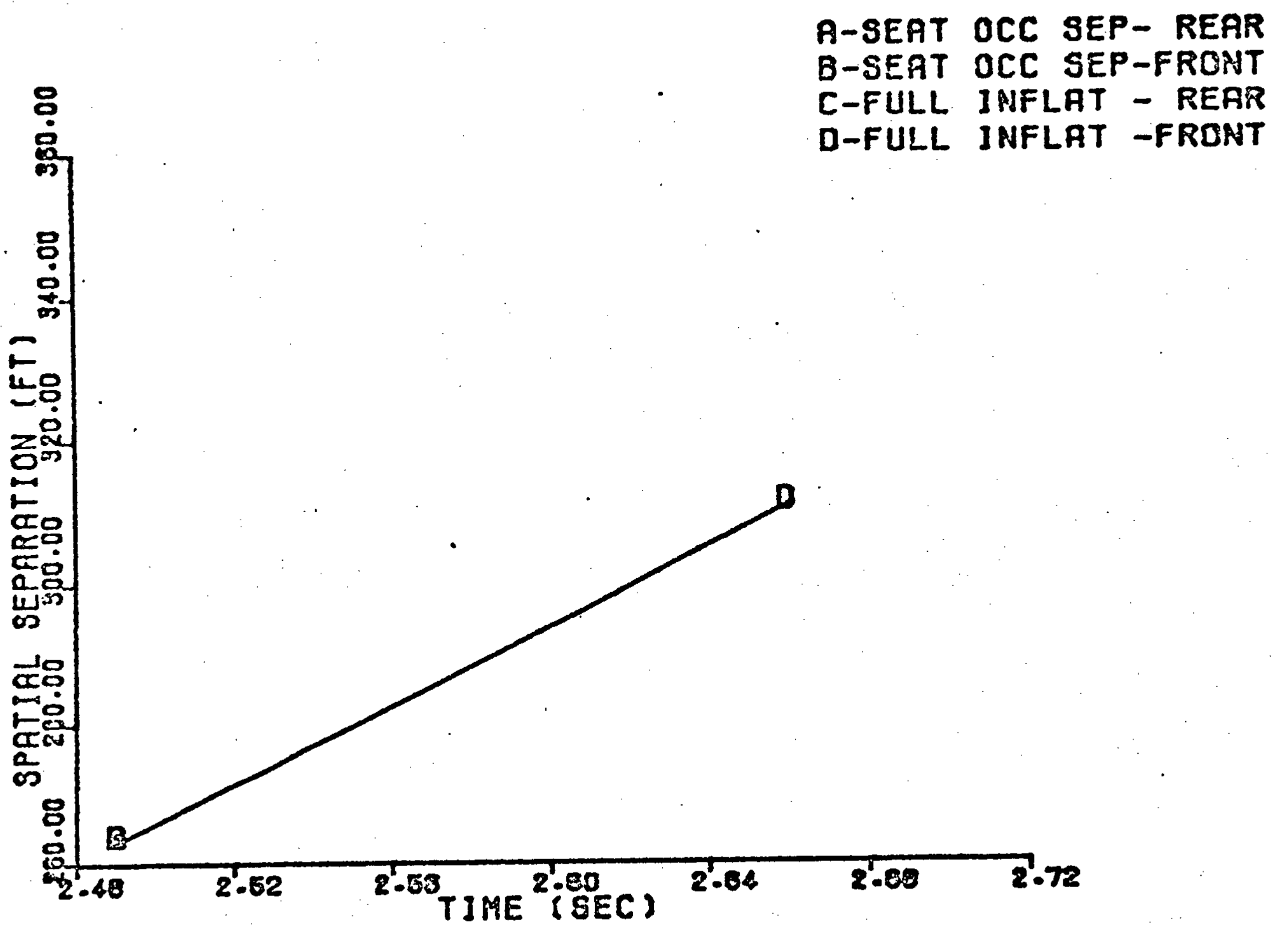


Figure D-106

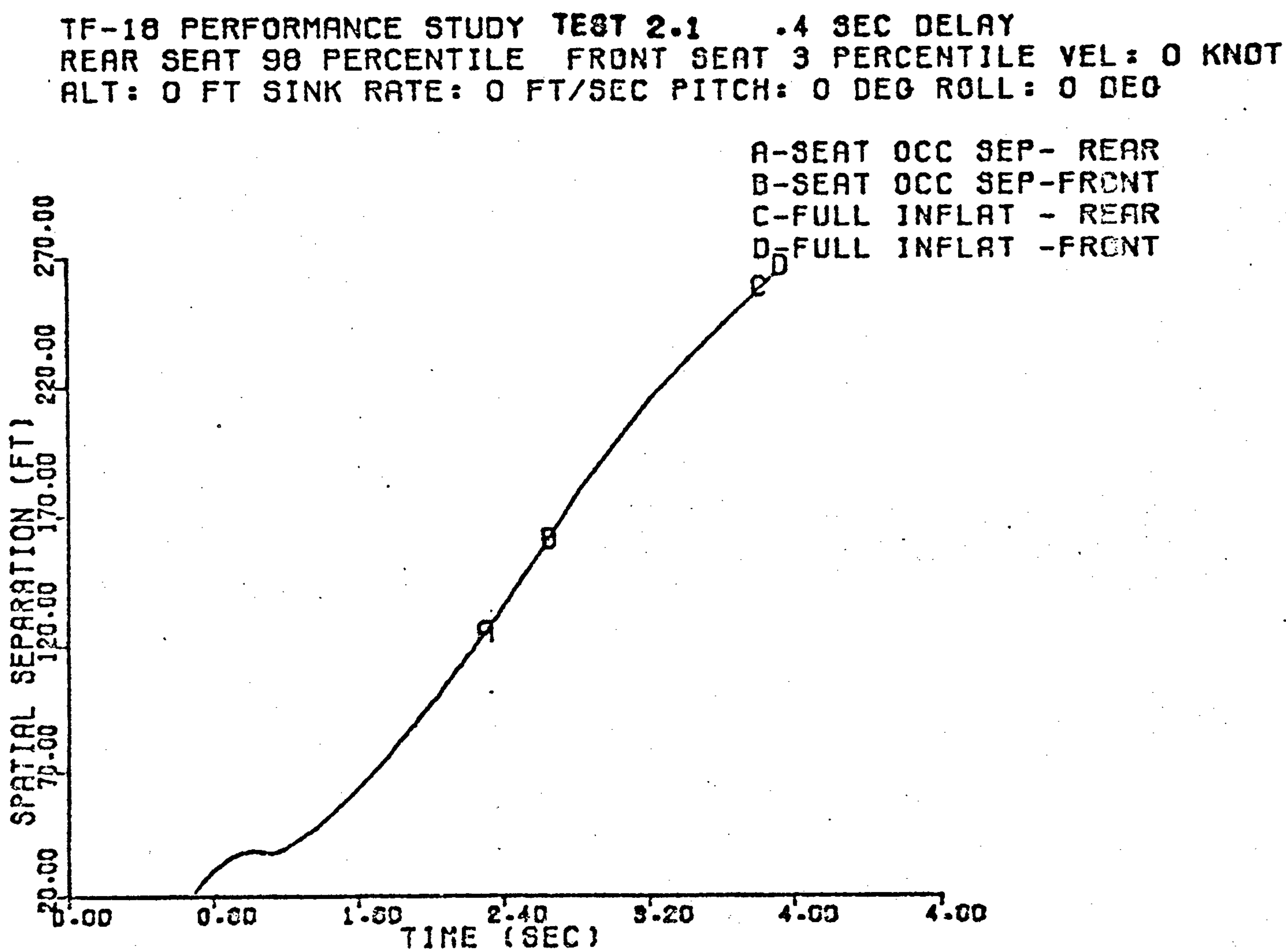

TF-18 PERFORMANCE STUDY TEST 2.1 .4 SEC DELAY
REAR SEAT 98 PERCENTILE FRONT SEAT 3 PERCENTILE VEL: 0 KNOT
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
20.00
70.00
120.00
170.00
220.00
270.00
TIME (SEC)
0.00
0.80
1.60
2.40
3.20
4.00
4.00
A
B
C
D

Figure D-107

TF-18 PERFORMANCE STUDY - TEST 2.1(A) .4 SEC DELAY
INITIAL VELOCITY: 0 KNOTS - BOTH SEATS DIVERGE LEFT
REAR SEAT 98 PERCENTILE FRONT SEAT 3 PERCENTILE

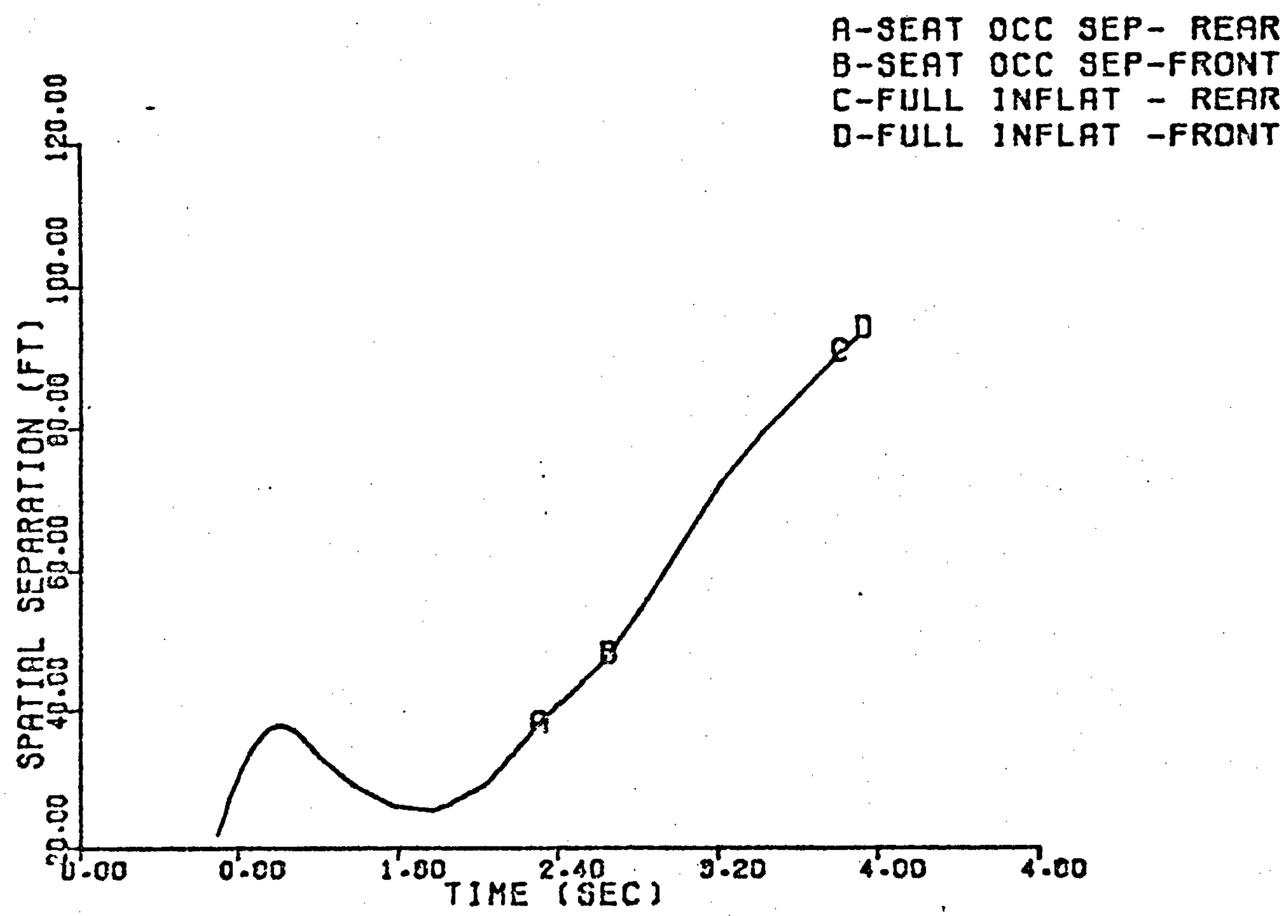


Figure D-108

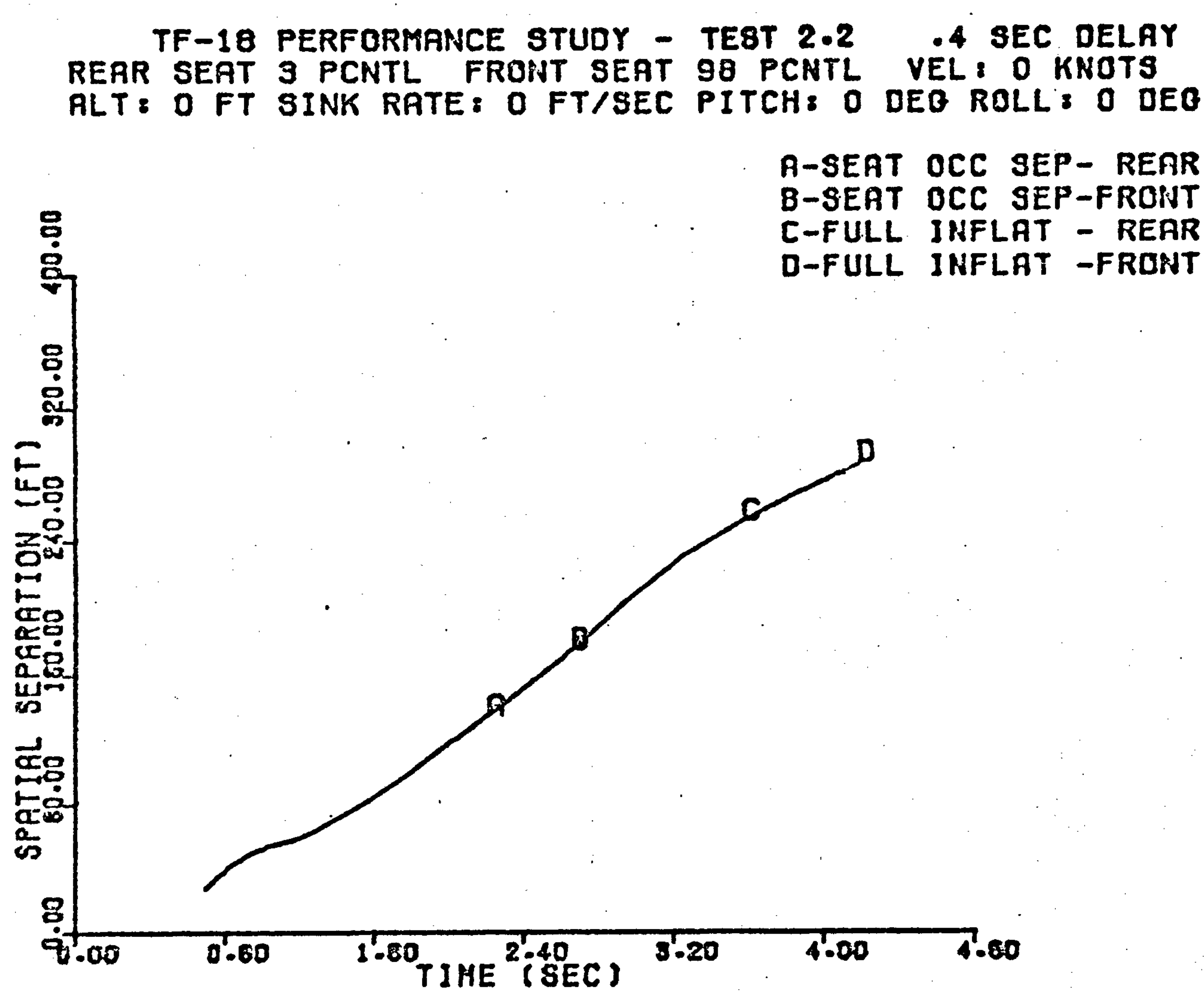

TF-18 PERFORMANCE STUDY - TEST 2.2 .4 SEC DELAY
REAR SEAT 3 PCNTL FRONT SEAT 98 PCNTL VEL: 0 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
80.00
160.00
240.00
320.00
400.00
TIME (SEC)
0.00
0.80
1.60
2.40
3.20
4.00
4.80

Figure D-109

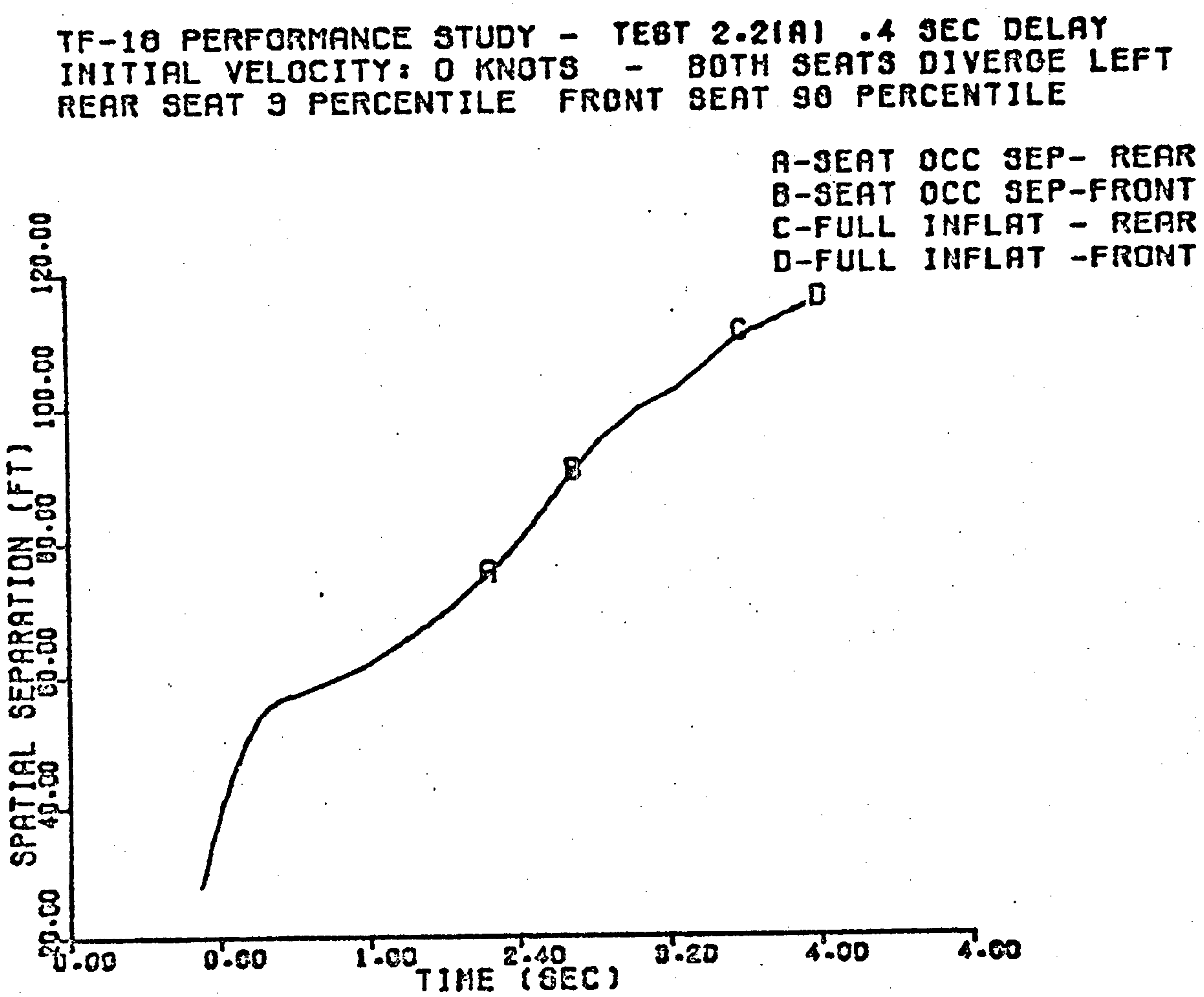

TF-18 PERFORMANCE STUDY - TEST 2.2(A) .4 SEC DELAY
INITIAL VELOCITY: 0 KNOTS - BOTH SEATS DIVERGE LEFT
REAR SEAT 3 PERCENTILE FRONT SEAT 98 PERCENTILE
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
120.00
100.00
TIME (SEC)
2.40
4.00

Figure D-110

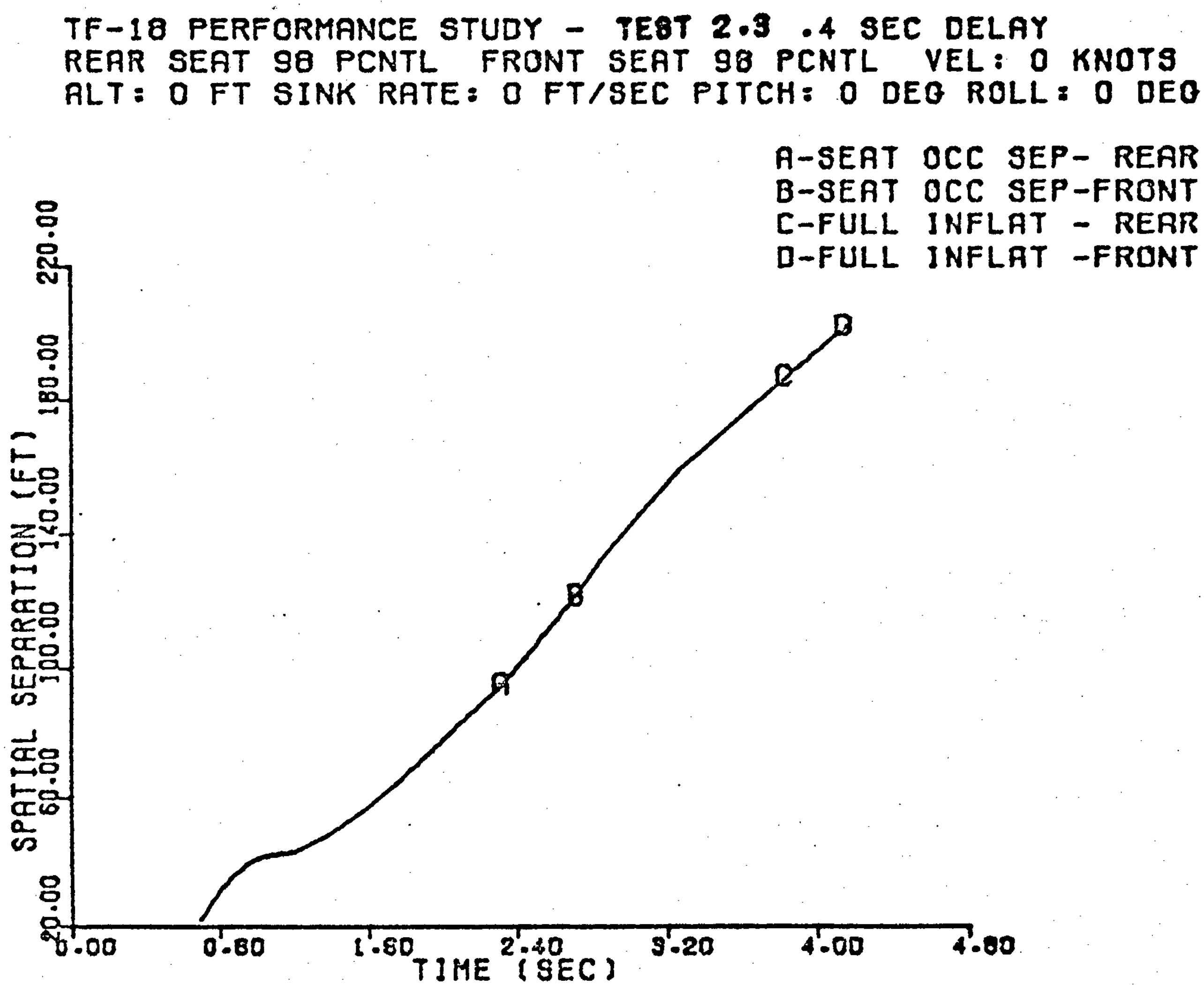
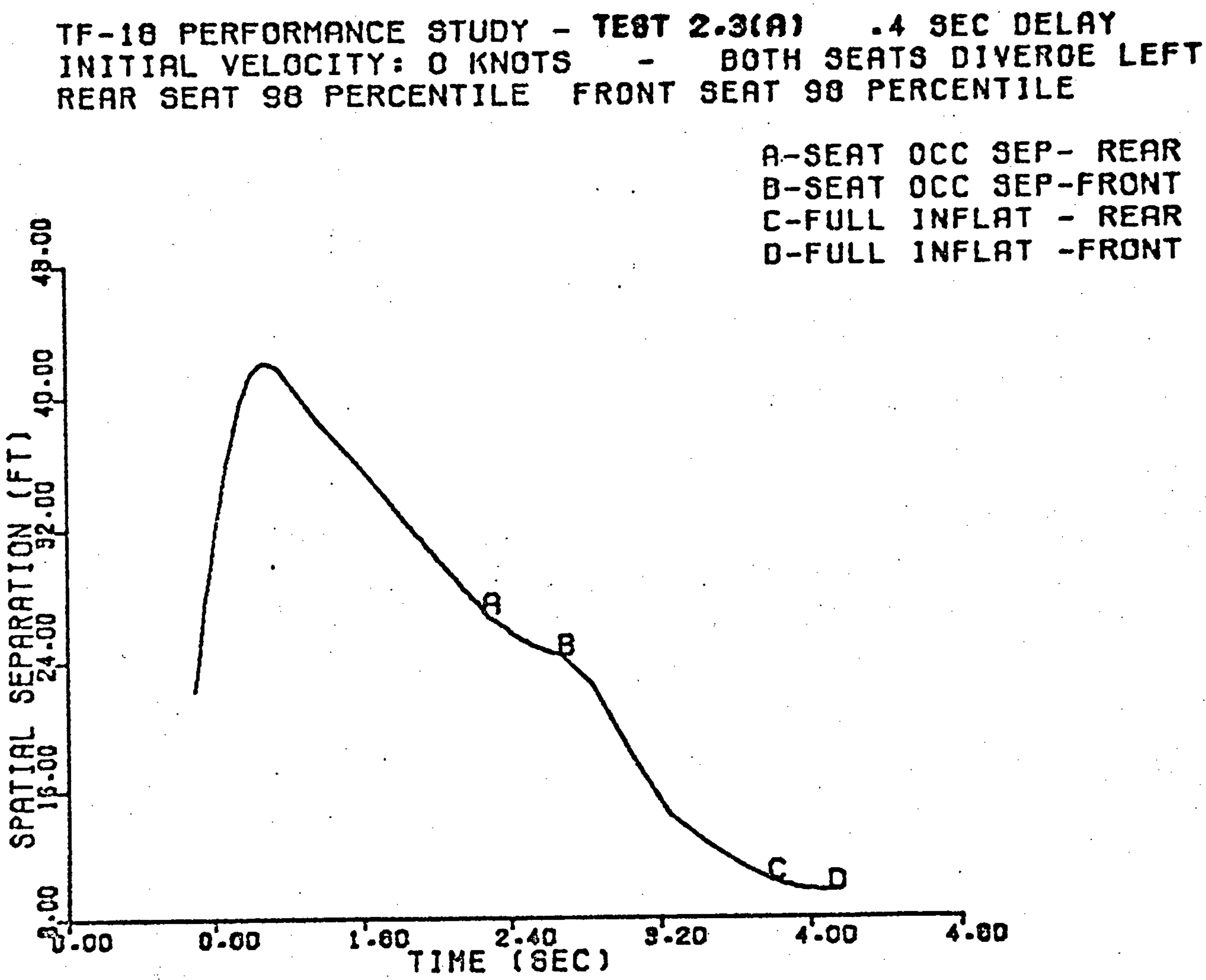
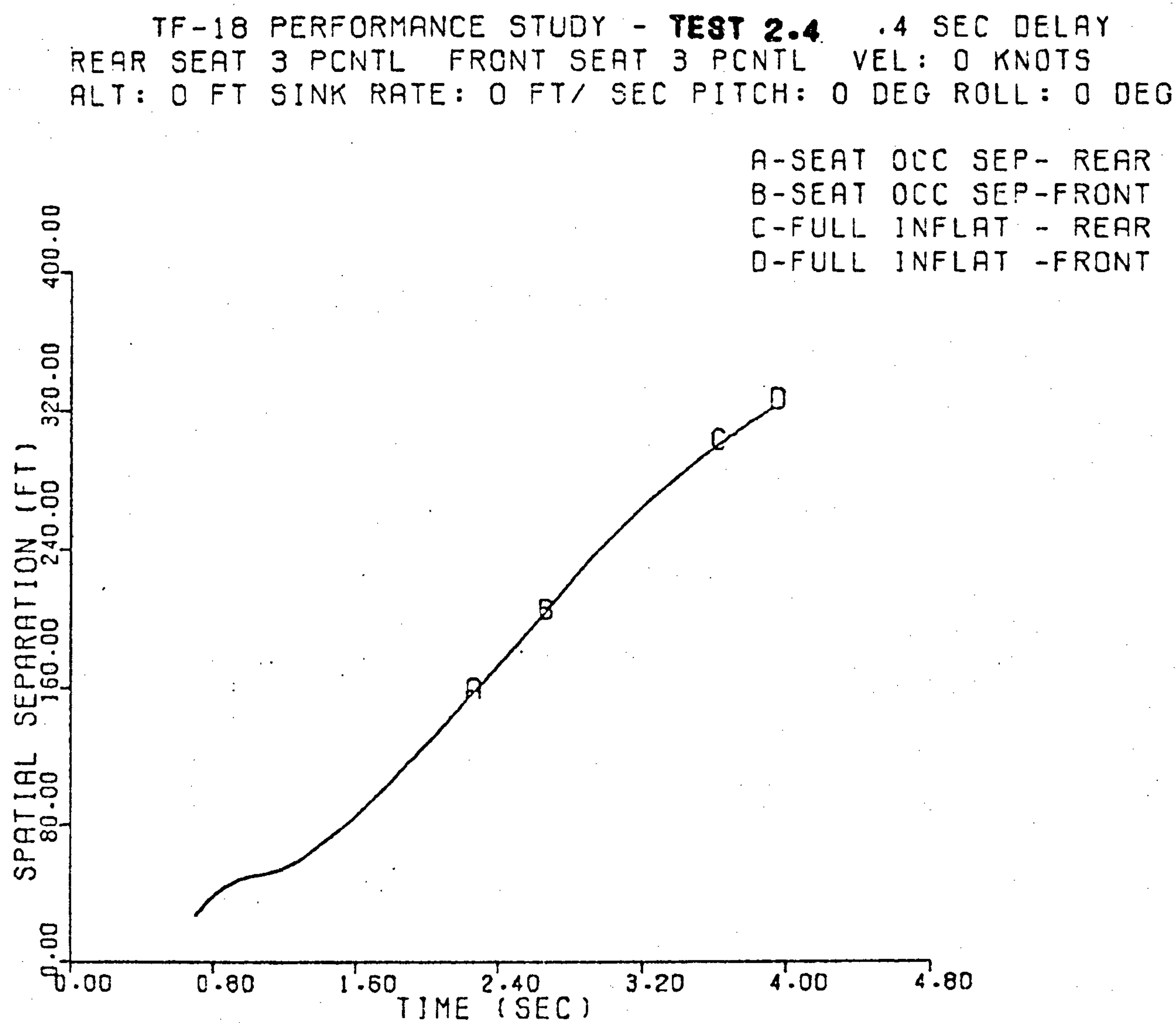

TF-18 PERFORMANCE STUDY - TEST 2.3 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 98 PCNTL VEL: 0 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
20.00
60.00
100.00
140.00
180.00
220.00
0.00
0.80
1.60
2.40
3.20
4.00
4.80
TIME (SEC)
A
B
C
D

Figure D-111



TF-18 PERFORMANCE STUDY - TEST 2.3(A) .4 SEC DELAY
INITIAL VELOCITY: 0 KNOTS - BOTH SEATS DIVERGE LEFT
REAR SEAT 98 PERCENTILE FRONT SEAT 98 PERCENTILE
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
TIME (SEC)

Figure D-112



TF-18 PERFORMANCE STUDY - TEST 2.4 .4 SEC DELAY
REAR SEAT 3 PCNTL FRONT SEAT 3 PCNTL VEL: 0 KNOTS
ALT: 0 FT SINK RATE: 0 FT/ SEC PITCH: 0 DEG ROLL: 0 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
80.00
160.00
240.00
320.00
400.00
0.00
0.80
1.60
2.40
3.20
4.00
4.80
TIME (SEC)
A
B
C
D

Figure D-113

TF-18 PERFORMANCE STUDY - TEST 2.4(A) .4 SEC DELAY
INITIAL VELOCITY: 0 KNOTS - BOTH SEATS DIVERGE LEFT
REAR SEAT 3 PERCENTILE FRONT SEAT 3 PERCENTILE

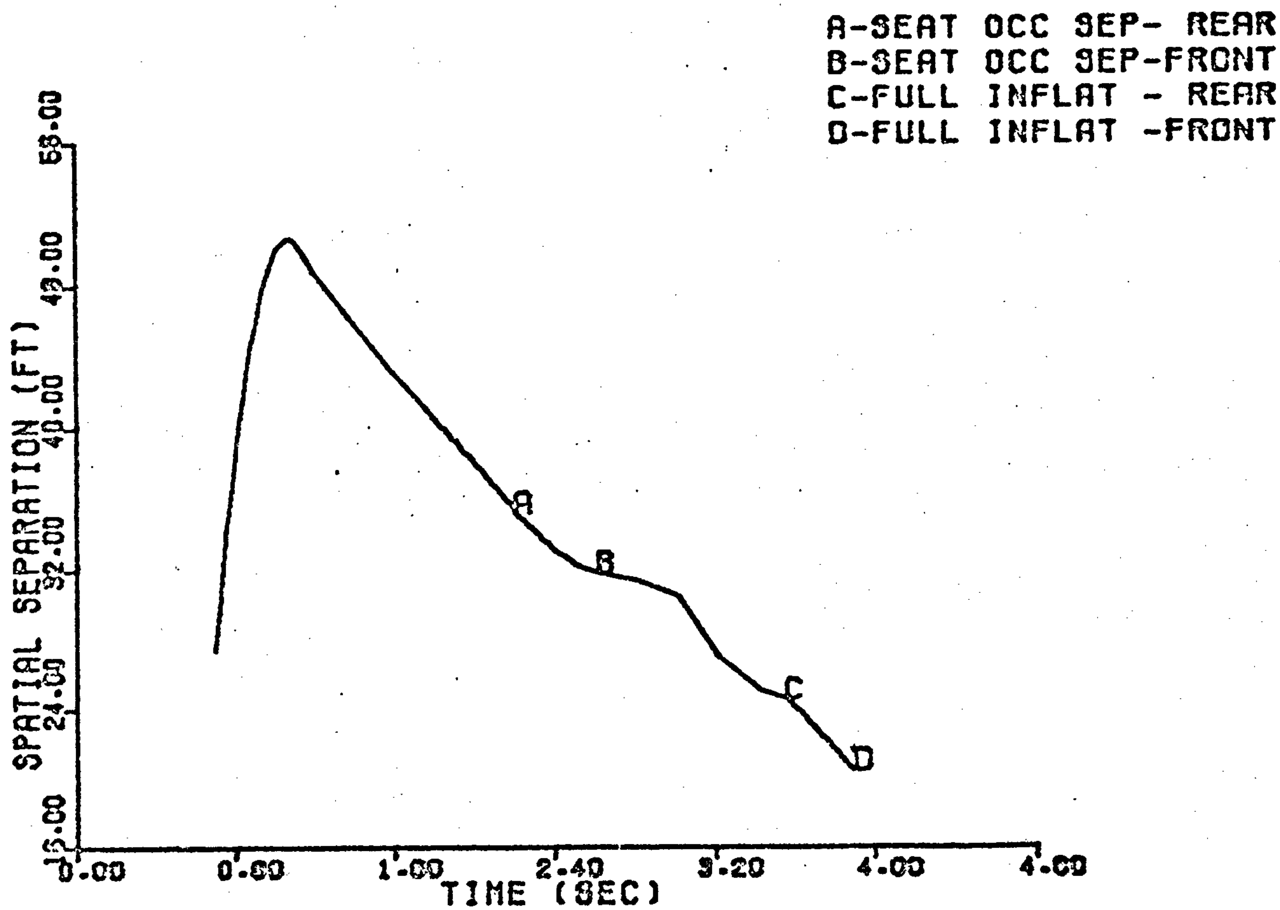


Figure D-114

TF-18 PERFORMANCE STUDY - TEST 2.5
INITIAL VELOCITY: 100 KNOTS - .4 SEC DELAY
SEATS DIVERGE IN OPPOSITE DIRECTIONS

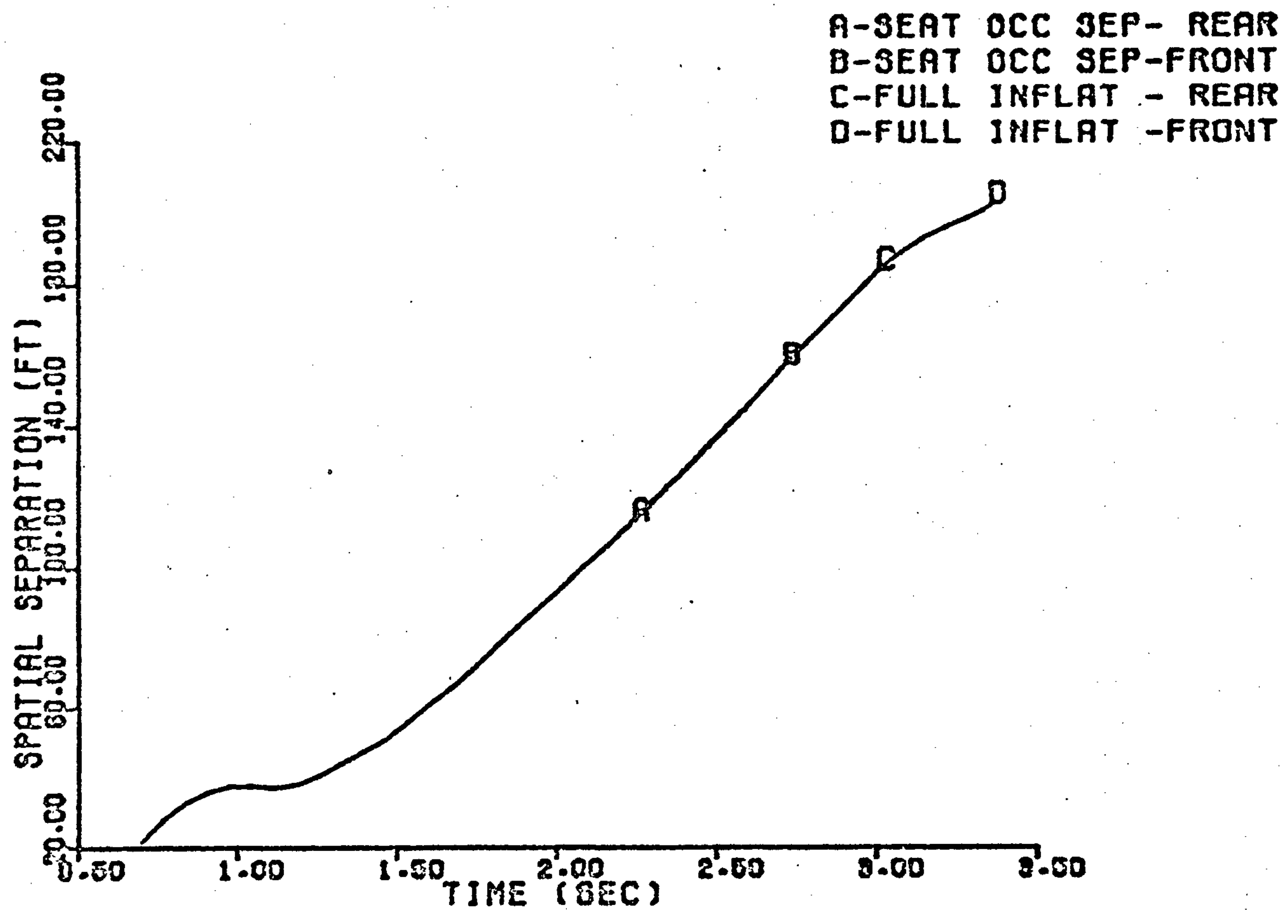


Figure D-115

TF-18 PERFORMANCE STUDY - TEST 2.5(A)
INITIAL VELOCITY: 100 KNOTS .4 SEC DELAY
BOTH SEATS DIVERGE LEFT

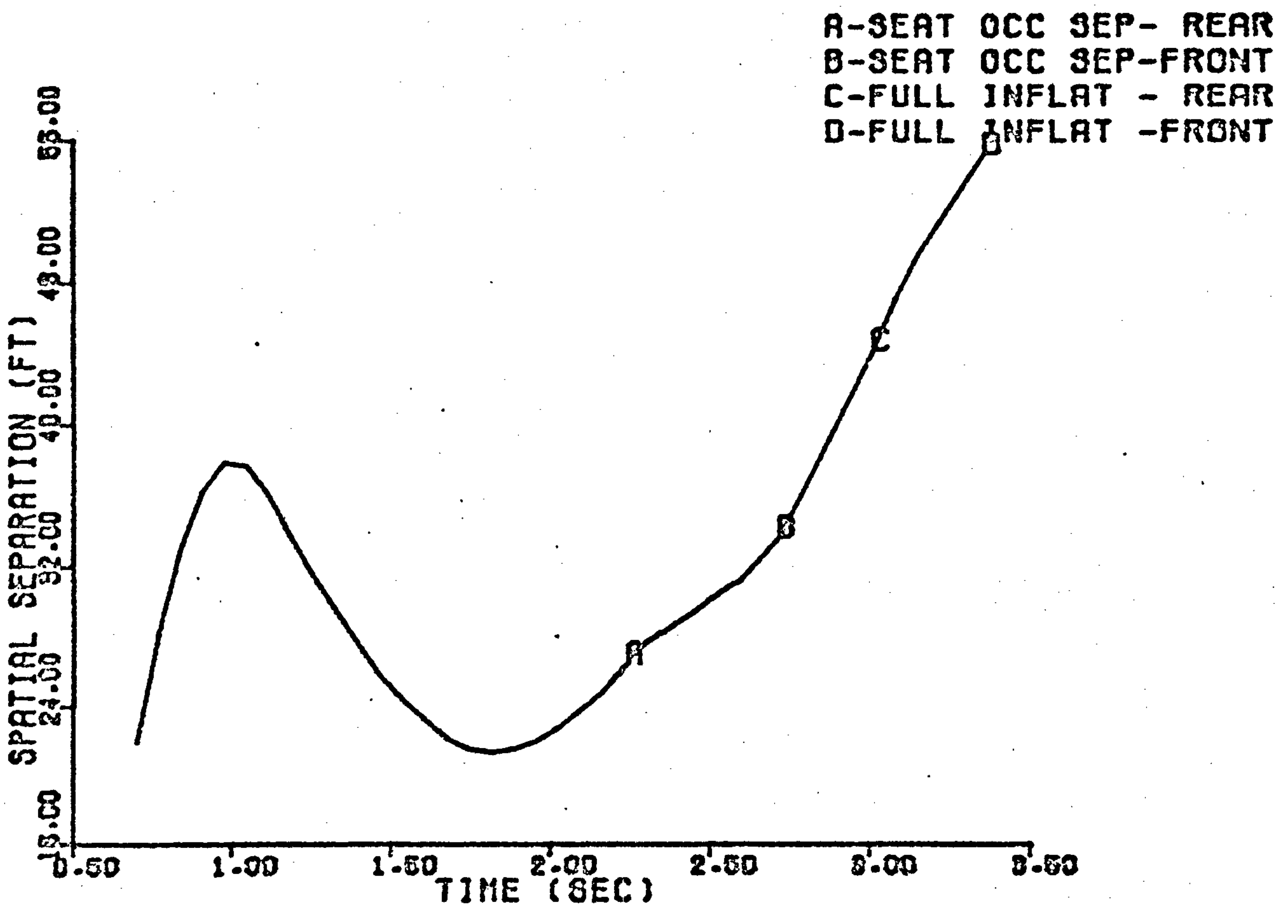


Figure D-116

TF-18 PERFORMANCE STUDY - TEST 2.6
INITIAL VELOCITY: 150 KNOTS - .4 SEC DELAY
SEATS DIVERGE IN OPPOSITE DIRECTIONS

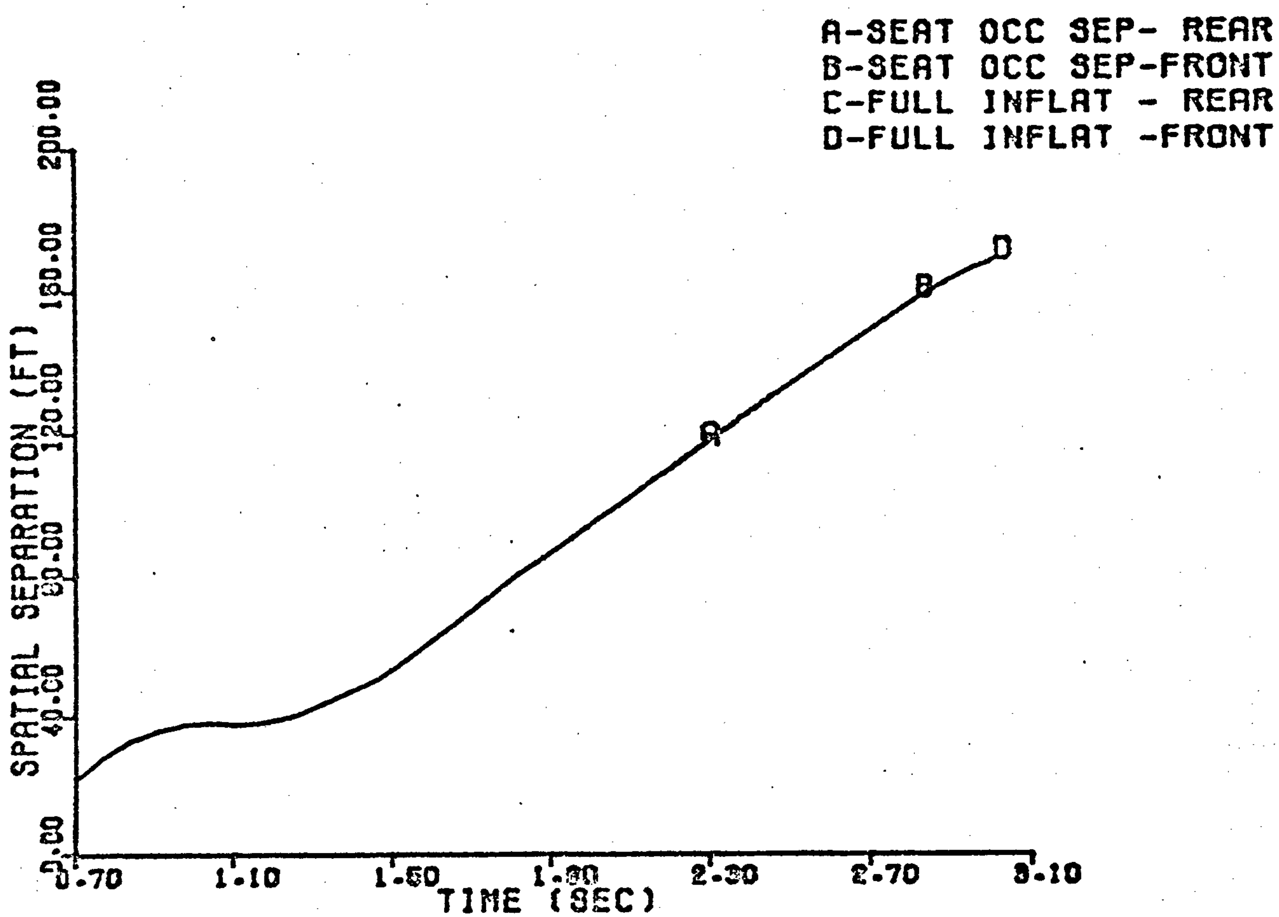


Figure D-117

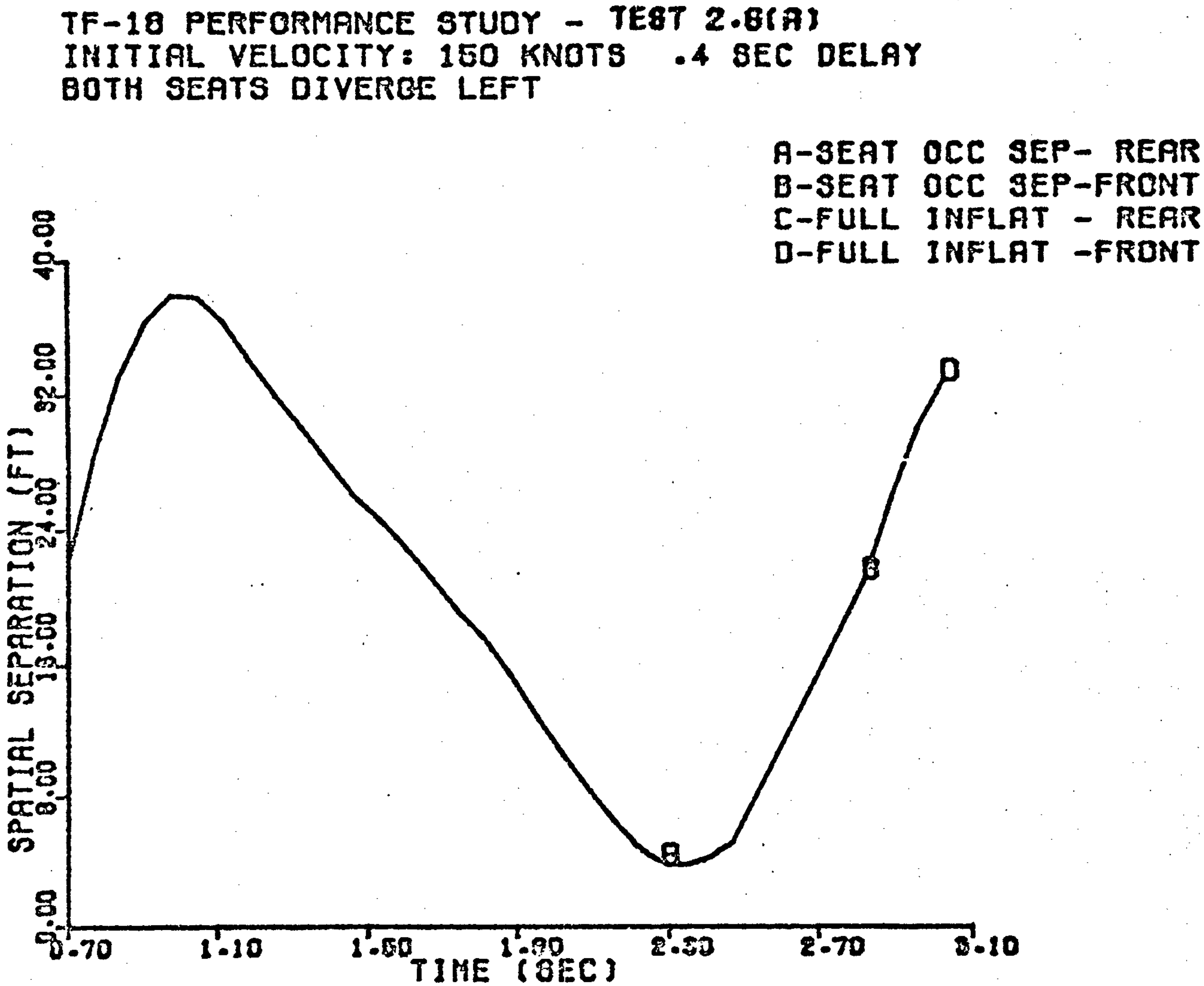

TF-18 PERFORMANCE STUDY - TEST 2.8(A)
INITIAL VELOCITY: 150 KNOTS .4 SEC DELAY
BOTH SEATS DIVERGE LEFT
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
8.00
16.00
24.00
32.00
40.00
TIME (SEC)
0.70
1.10
1.50
1.90
2.30
2.70
3.10
B
B
D

Figure D-118

TF-18 PERFORMANCESTUDY - TEST 2.7 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 200 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

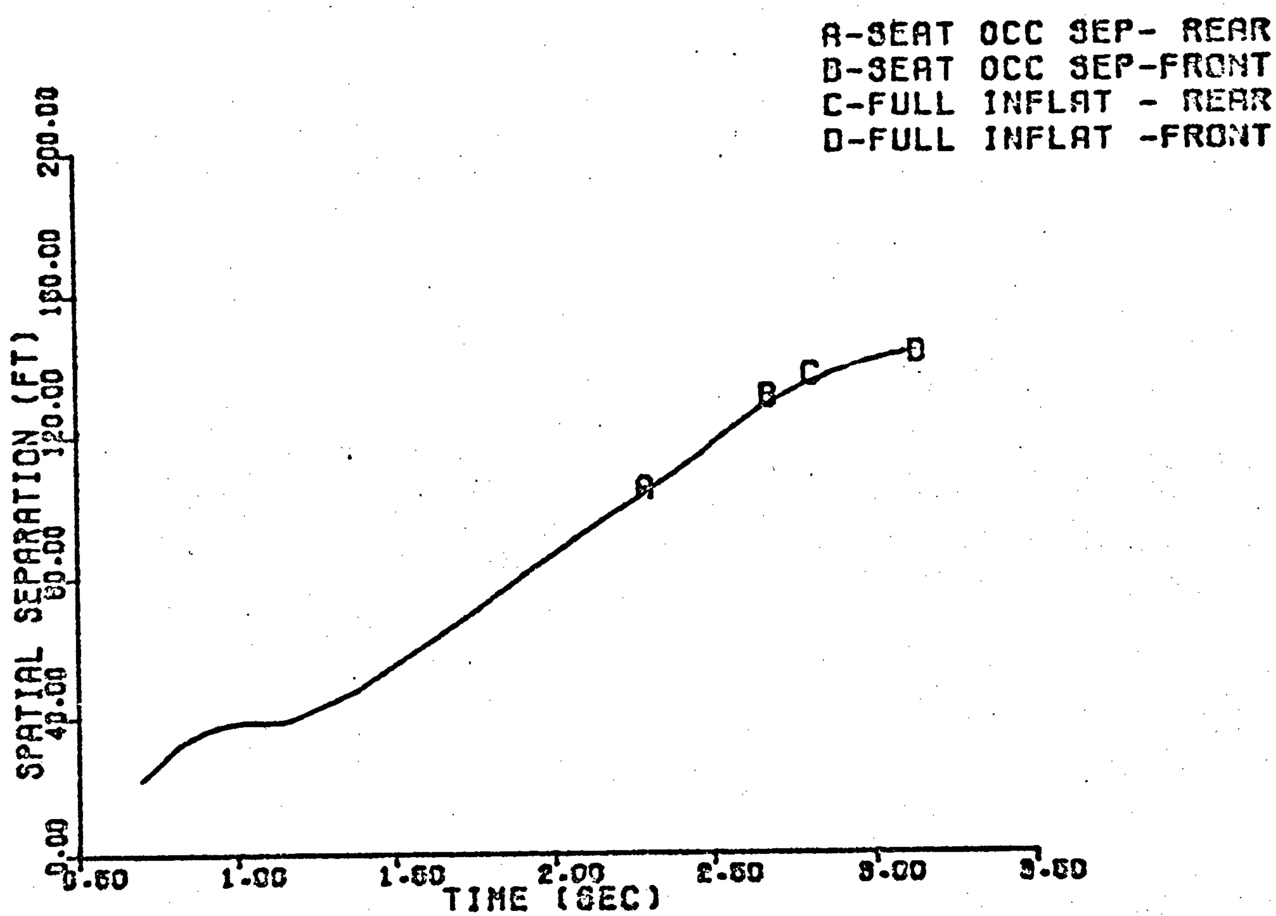


Figure D-119

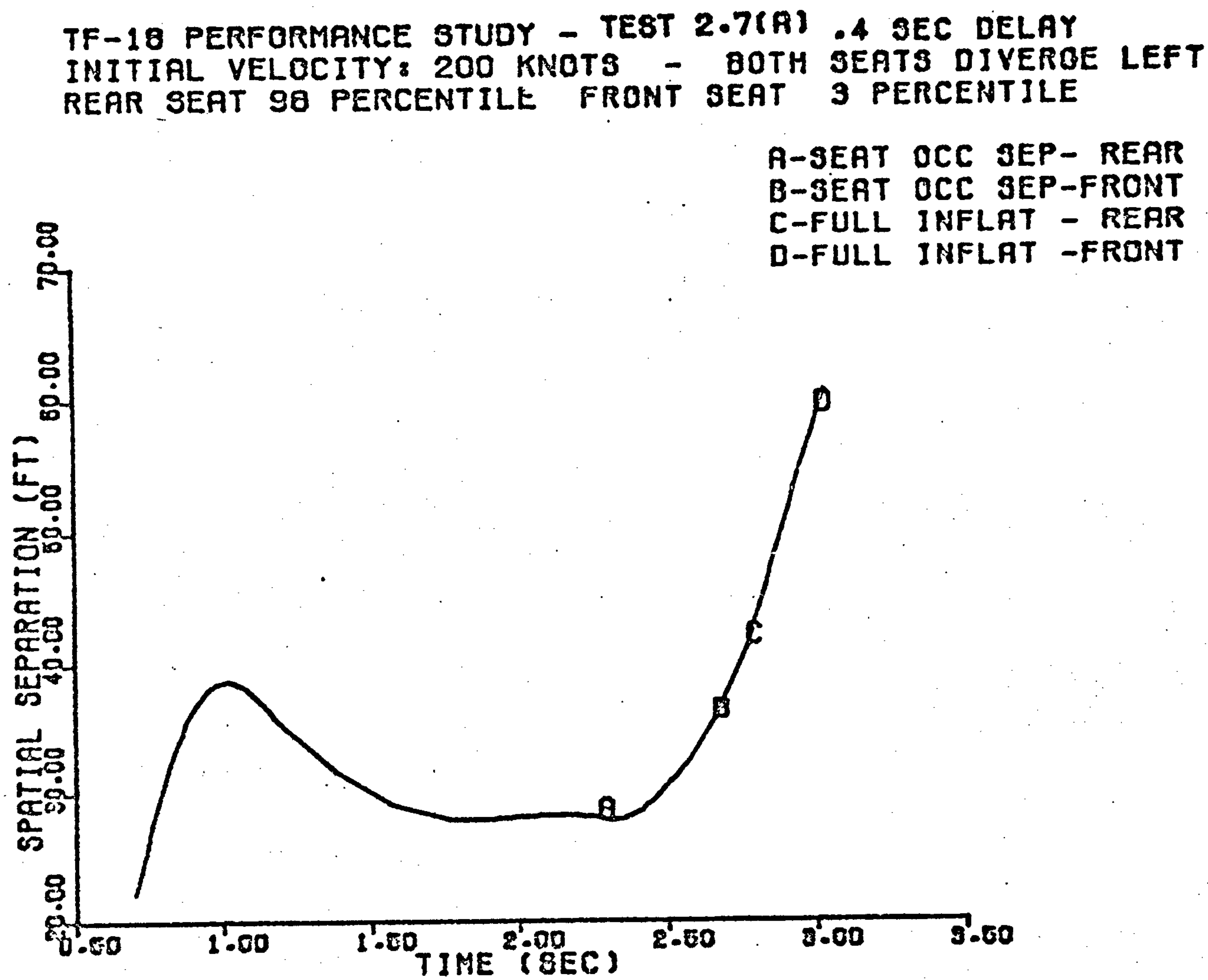

TF-18 PERFORMANCE STUDY - TEST 2.7(A) .4 SEC DELAY
INITIAL VELOCITY: 200 KNOTS - BOTH SEATS DIVERGE LEFT
REAR SEAT 98 PERCENTILE FRONT SEAT 3 PERCENTILE
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
20.00
30.00
40.00
50.00
60.00
70.00
TIME (SEC)
0.50
1.00
1.50
2.00
2.50
3.00
3.50
A
B
C
D

Figure D-120

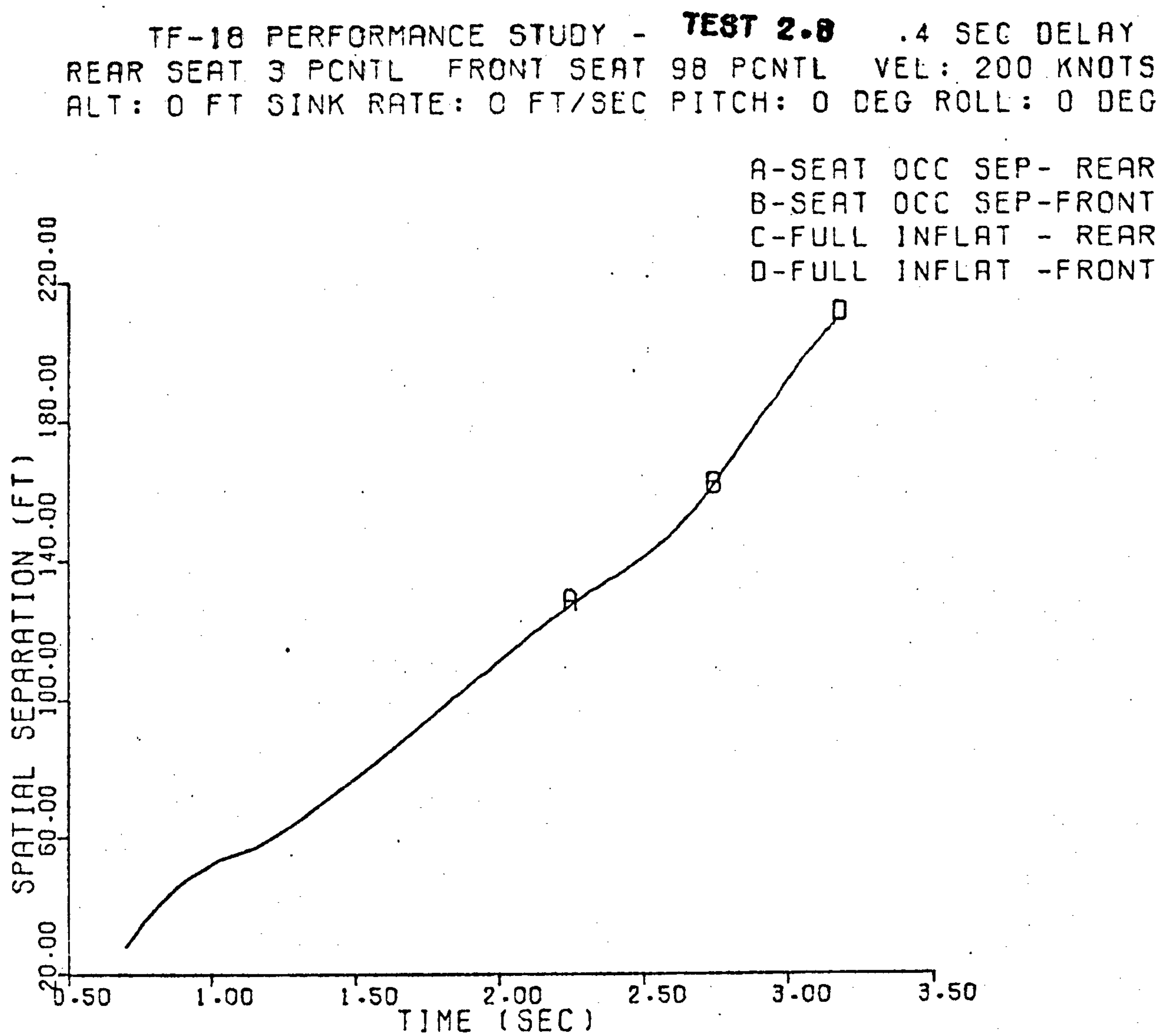

TF-18 PERFORMANCE STUDY - TEST 2.8 .4 SEC DELAY
REAR SEAT 3 PCNTL FRONT SEAT 98 PCNTL VEL: 200 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
220.00
180.00
140.00
100.00
60.00
20.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
TIME (SEC)
A
B
D

Figure D-121

TF-18 PERFORMANCE STUDY - TEST 2.8(A) .4 SEC DELAY
INITIAL VELOCITY: 200 KNOTS - BOTH SEATS DIVERGE LEFT
REAR SEAT 3 PERCENTILE FRONT SEAT 98 PERCENTILE

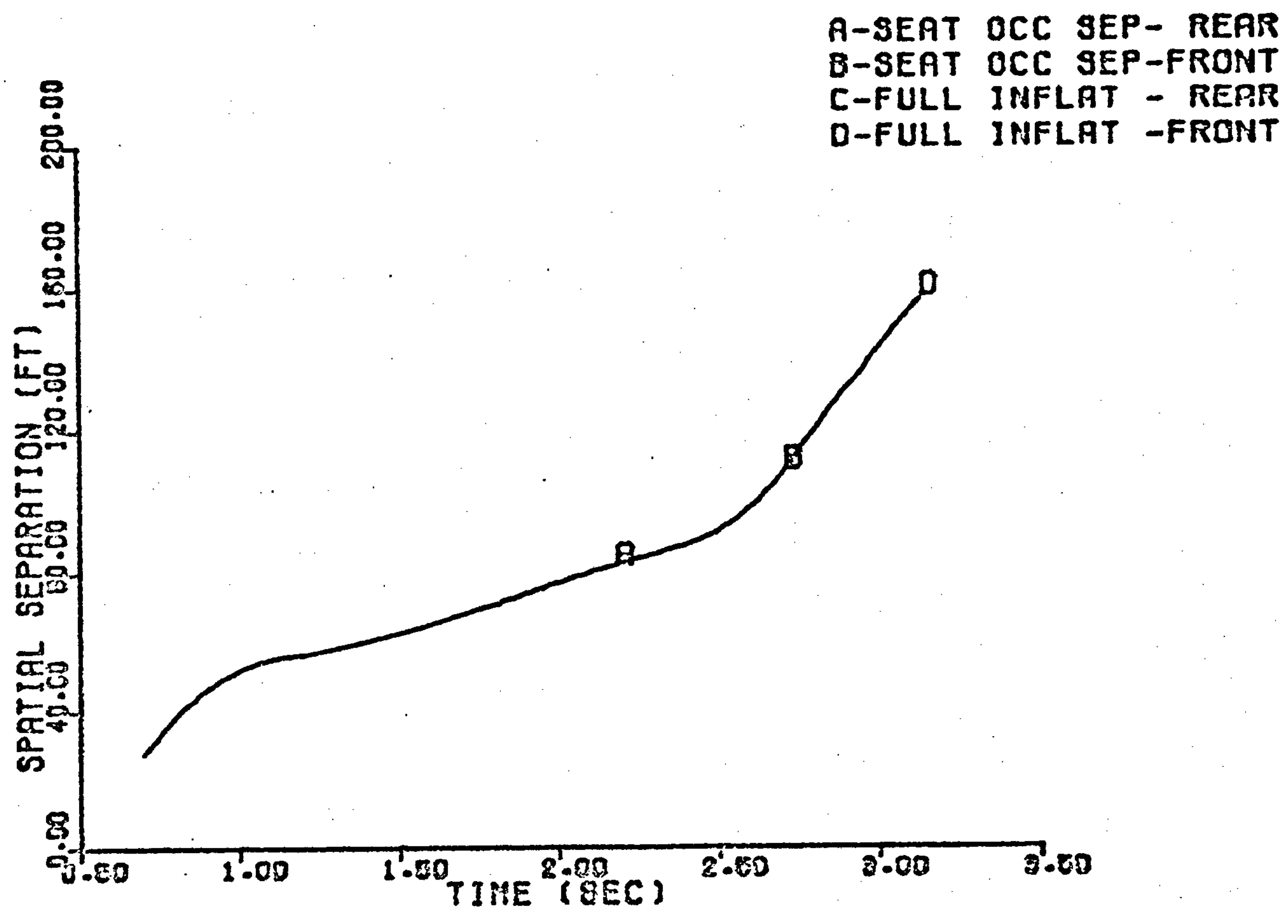


Figure D-122

TF-18 PERFORMANCE STUDY - TEST 2.9 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 98 PCNTL VEL: 200 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT

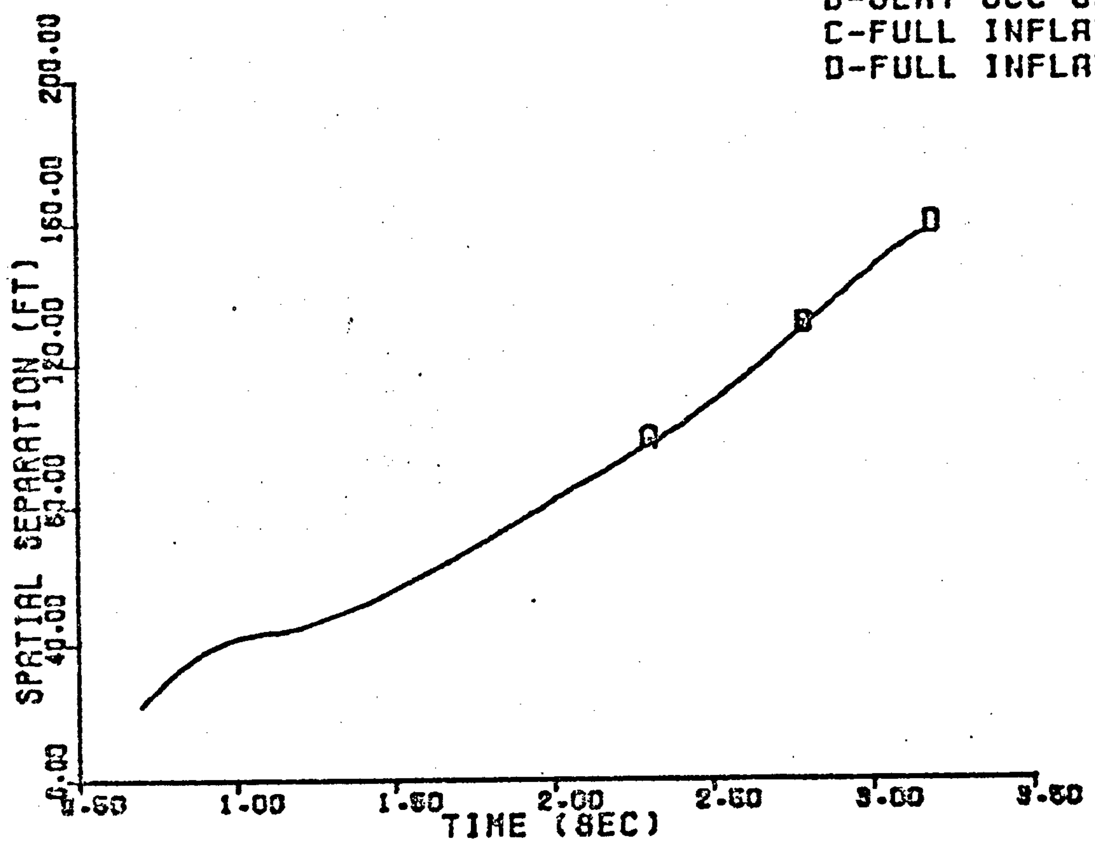


Figure D-123

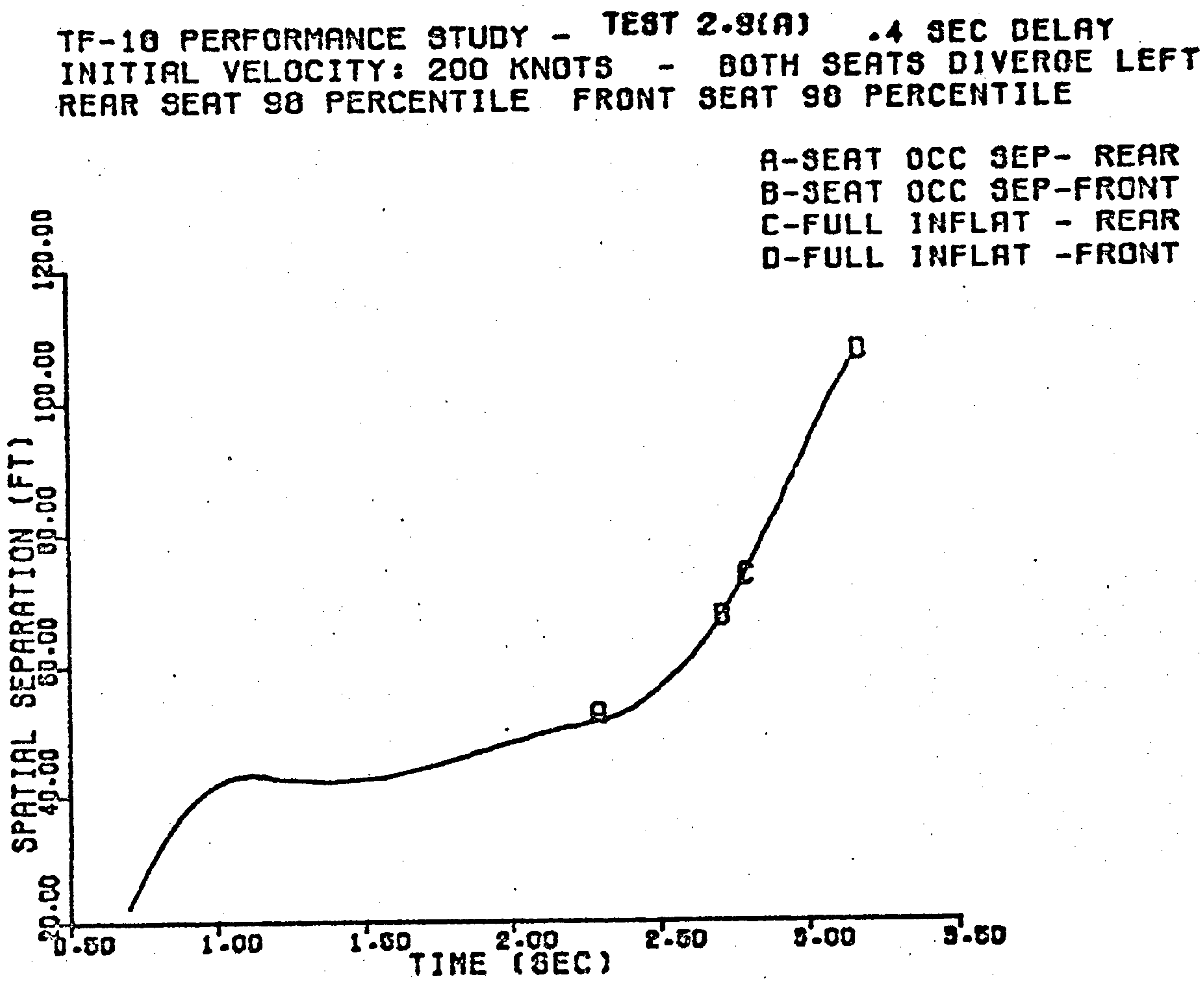
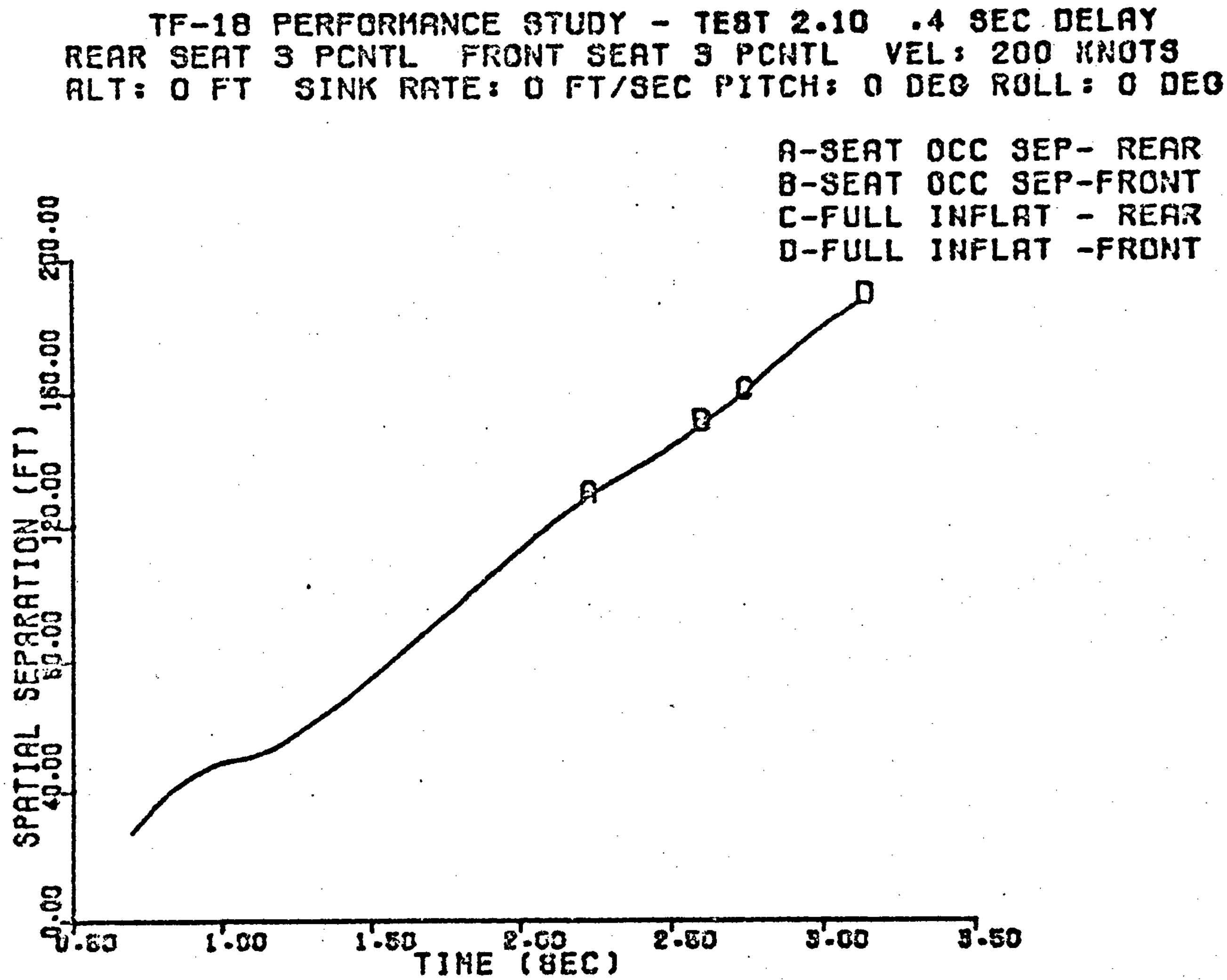

TF-18 PERFORMANCE STUDY - TEST 2.9(A) .4 SEC DELAY
INITIAL VELOCITY: 200 KNOTS - BOTH SEATS DIVERGE LEFT
REAR SEAT 98 PERCENTILE FRONT SEAT 98 PERCENTILE
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
20.00
40.00
60.00
80.00
100.00
120.00
TIME (SEC)
0.50
1.00
1.50
2.00
2.50
3.00
3.50
A
B
C
D

Figure D-124



TF-18 PERFORMANCE STUDY - TEST 2.10 .4 SEC DELAY
REAR SEAT 3 PCNTL FRONT SEAT 3 PCNTL VEL: 200 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
40.00
80.00
120.00
160.00
200.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
TIME (SEC)

Figure D-125

TF-18 PERFORMANCE STUDY - TEST 2.10(A) .4 SEC DELAY
INITIAL VELOCITY: 200 KNOTS - BOTH SEATS DIVERGE LEFT
REAR SEAT 3 PERCENTILE FRONT SEAT 3 PERCENTILE

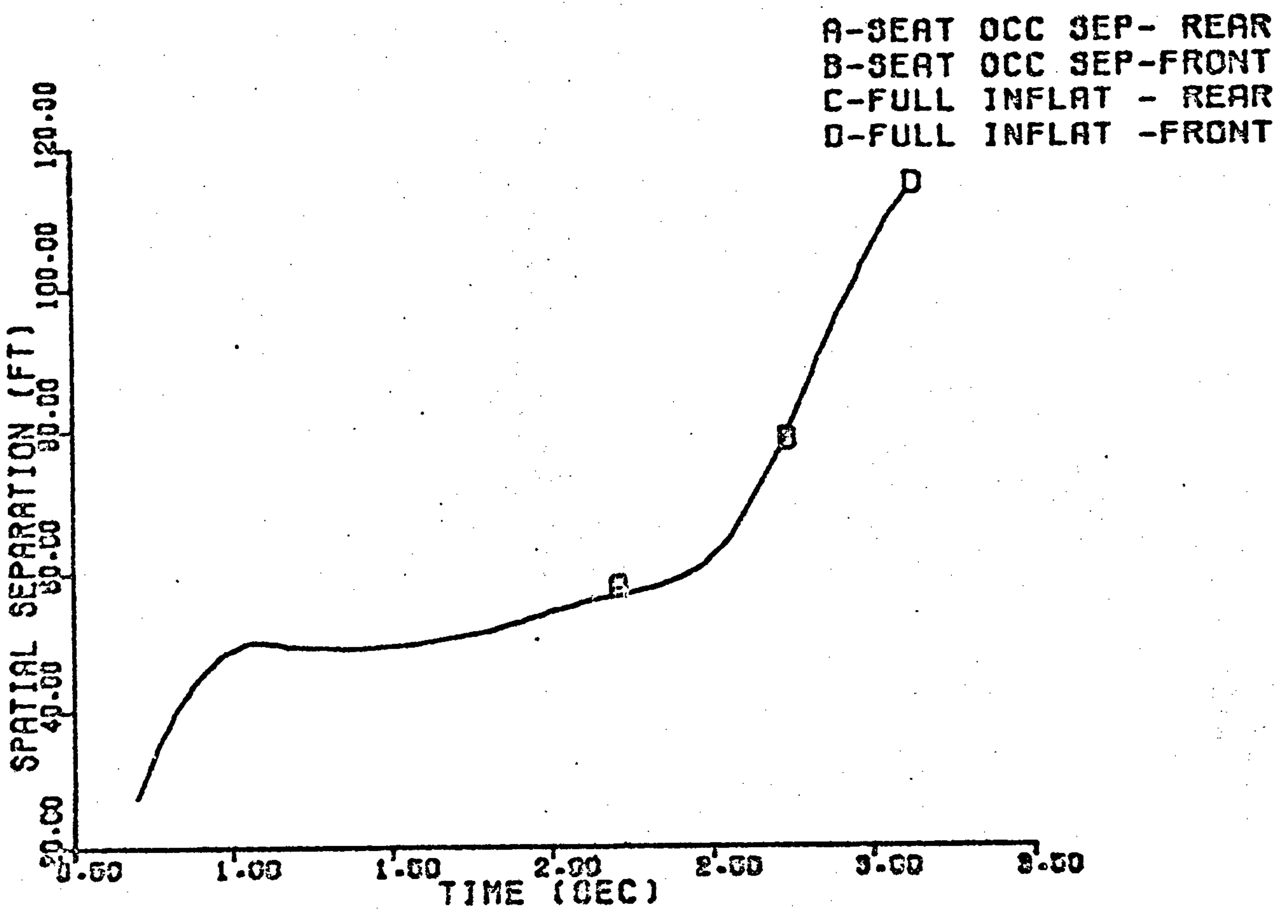


Figure D-126

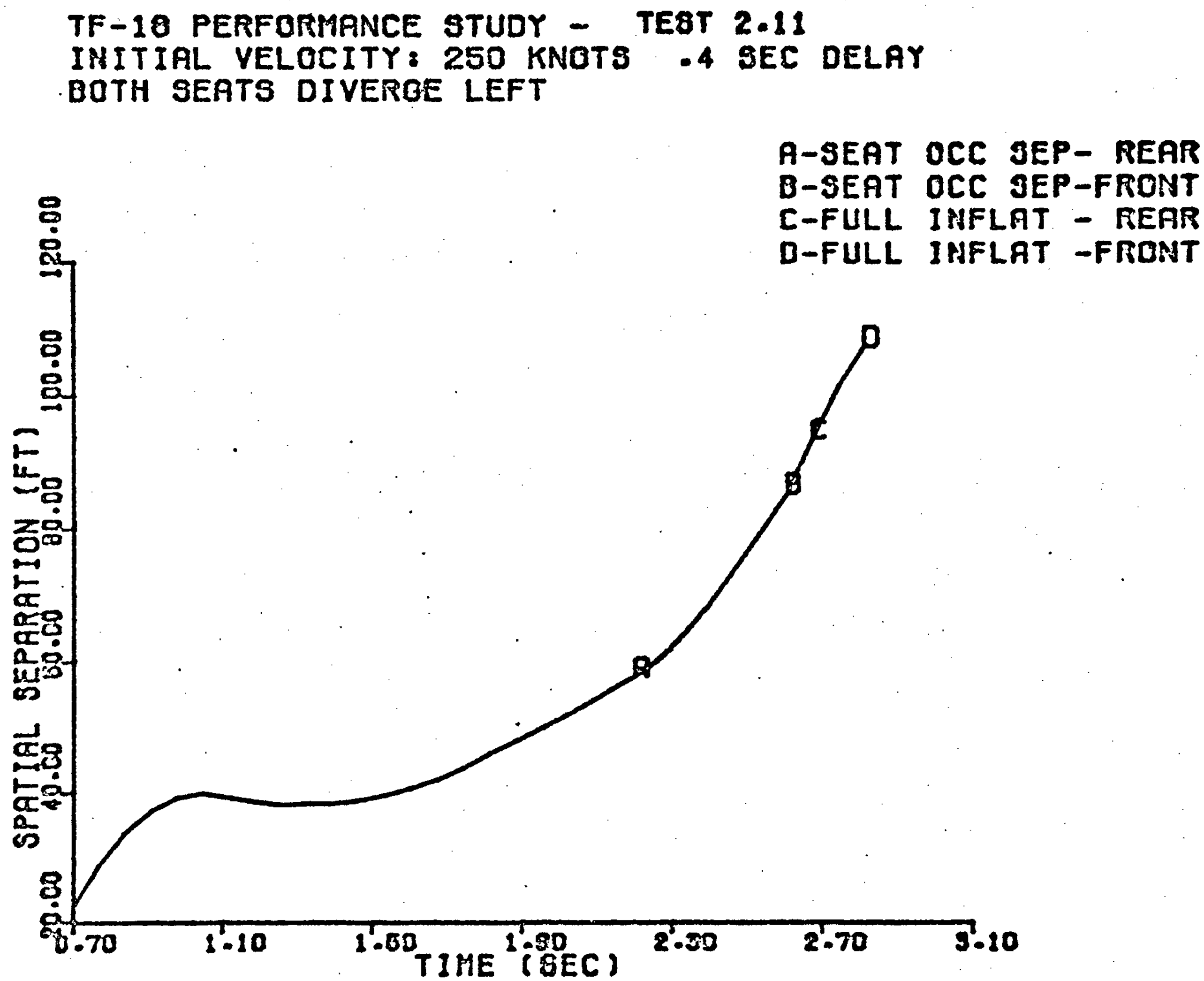

TF-18 PERFORMANCE STUDY - TEST 2.11
INITIAL VELOCITY: 250 KNOTS .4 SEC DELAY
BOTH SEATS DIVERGE LEFT
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
20.00
40.00
60.00
80.00
100.00
120.00
0.70
1.10
1.50
1.90
2.30
2.70
3.10
TIME (SEC)

Figure D-127

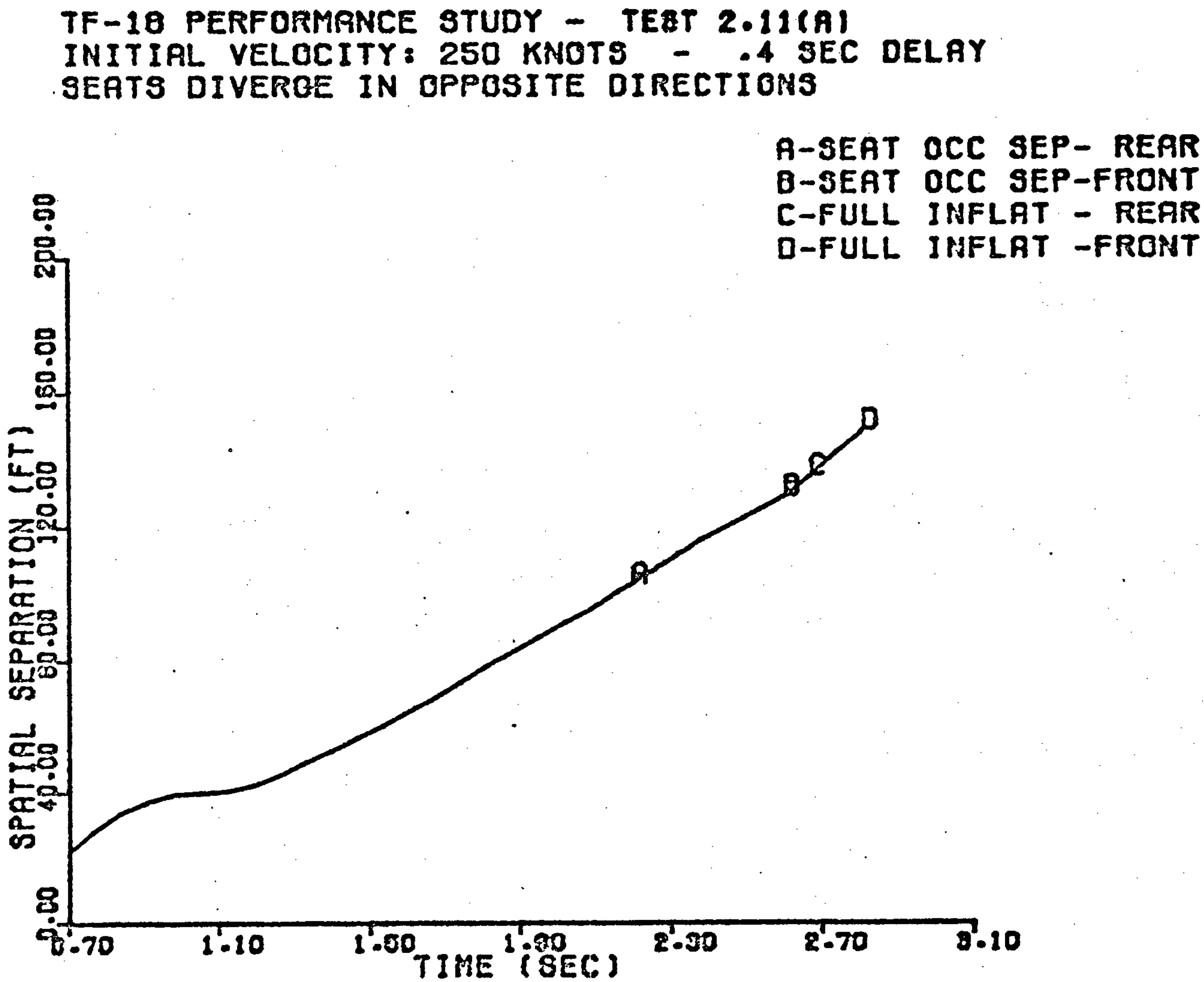
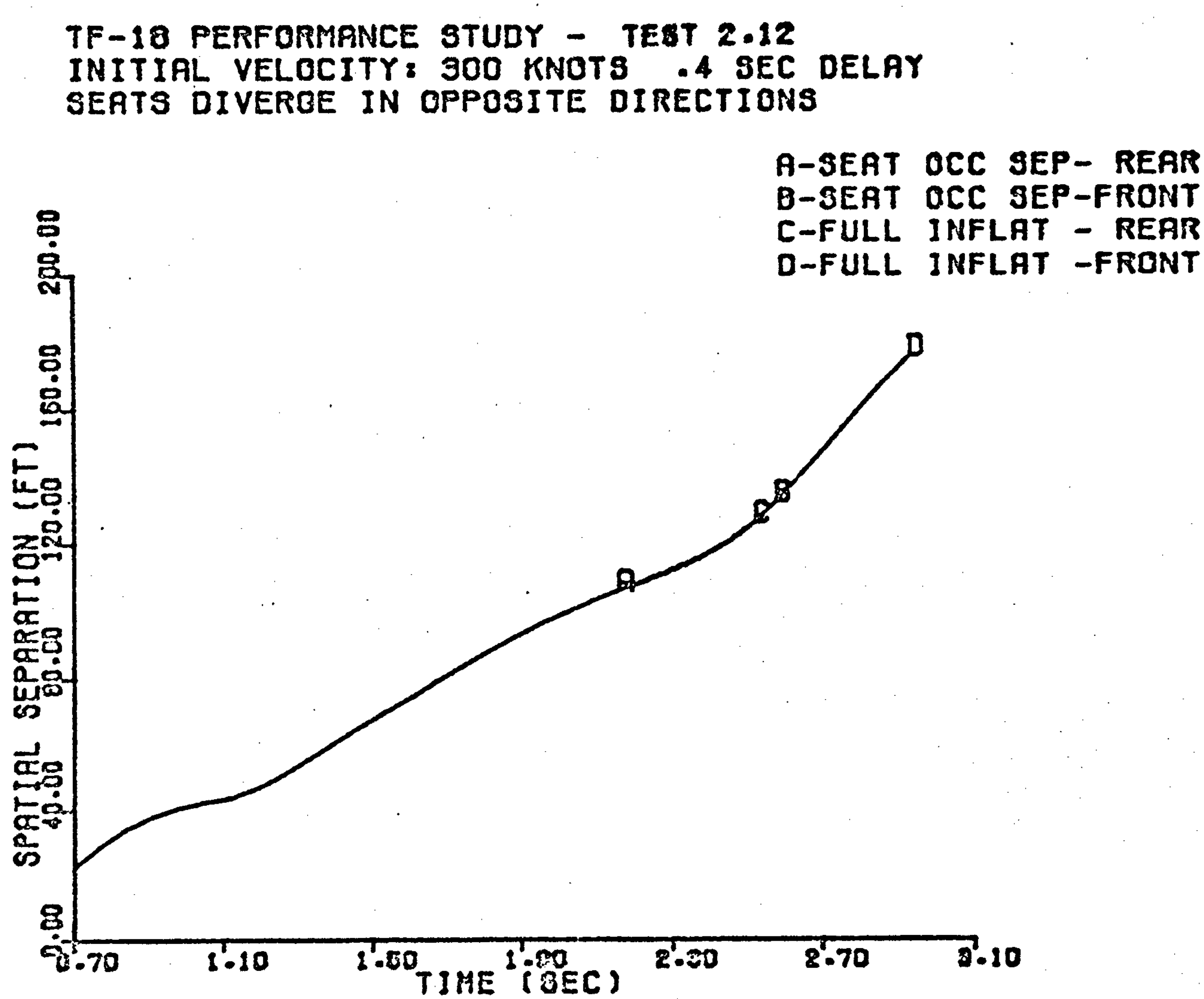

TF-18 PERFORMANCE STUDY - TEST 2.11(A)
INITIAL VELOCITY: 250 KNOTS - .4 SEC DELAY
SEATS DIVERGE IN OPPOSITE DIRECTIONS
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
40.00
80.00
120.00
160.00
200.00
TIME (SEC)
0.70
1.10
1.50
1.90
2.30
2.70
3.10
A
B
C
D

Figure D-128



TF-18 PERFORMANCE STUDY - TEST 2.12
INITIAL VELOCITY: 300 KNOTS .4 SEC DELAY
SEATS DIVERGE IN OPPOSITE DIRECTIONS
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
TIME (SEC)

Figure D-129

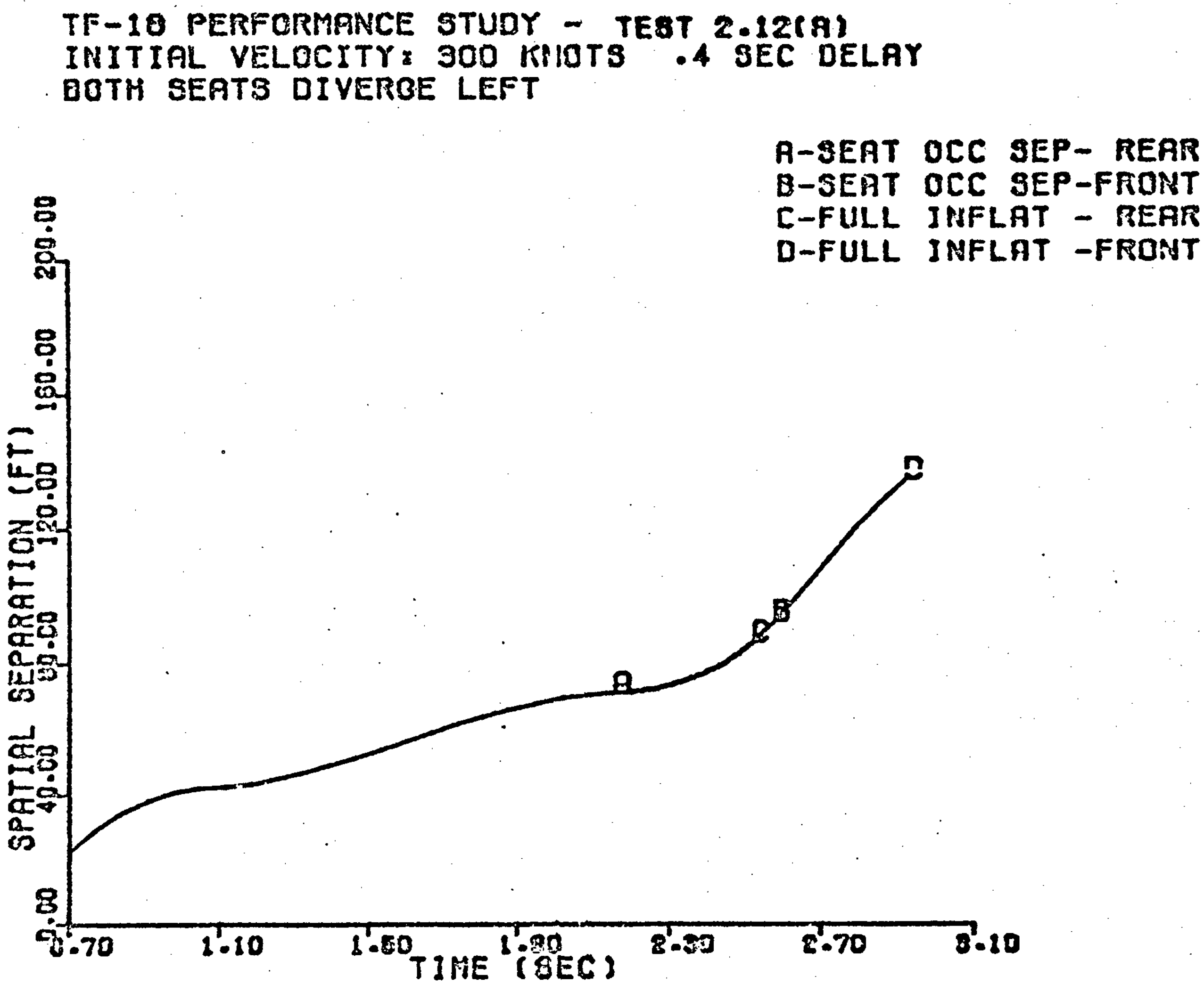

TF-18 PERFORMANCE STUDY - TEST 2.12(A)
INITIAL VELOCITY: 300 KNOTS .4 SEC DELAY
BOTH SEATS DIVERGE LEFT
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
40.00
80.00
120.00
160.00
200.00
0.70
1.10
1.50
1.90
2.30
2.70
3.10
TIME (SEC)
A
C
B
D

Figure D-130

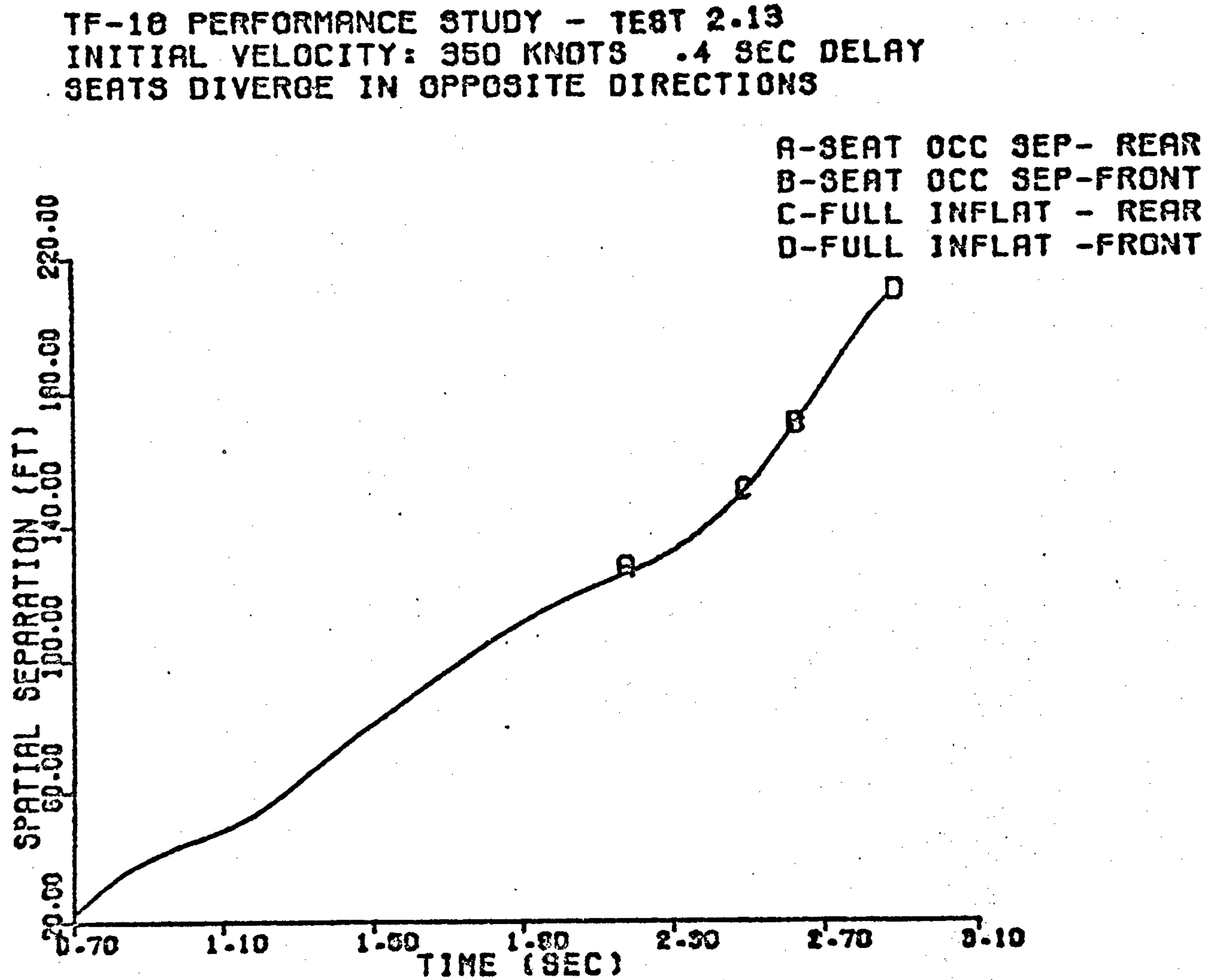

TF-18 PERFORMANCE STUDY - TEST 2.13
INITIAL VELOCITY: 350 KNOTS .4 SEC DELAY
SEATS DIVERGE IN OPPOSITE DIRECTIONS
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
A
B
C
D
SPATIAL SEPARATION (FT)
20.00
60.00
100.00
140.00
180.00
220.00
TIME (SEC)
0.70
1.10
1.50
1.90
2.30
2.70
3.10

Figure D-131

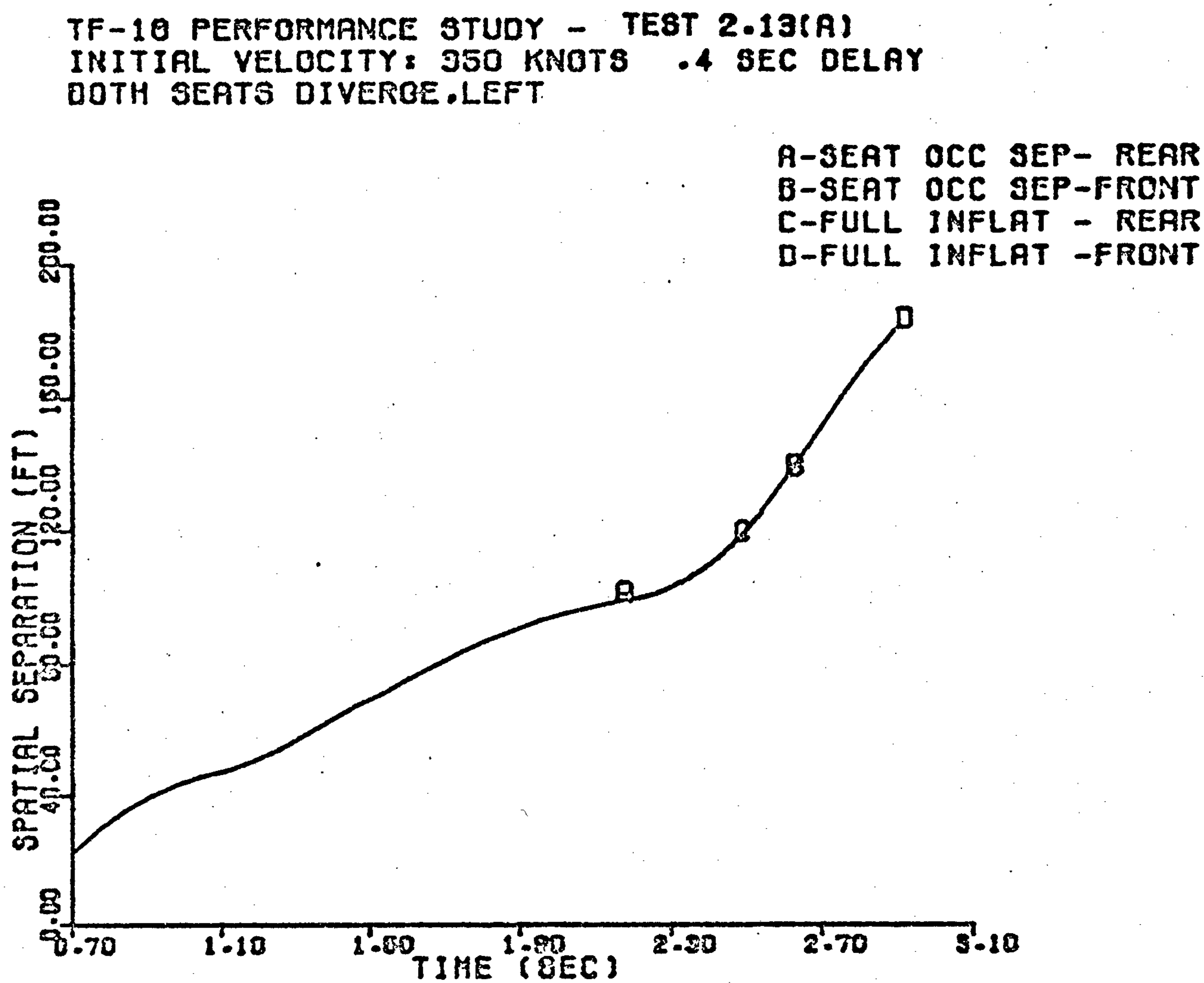

TF-18 PERFORMANCE STUDY - TEST 2.13(A)
INITIAL VELOCITY: 350 KNOTS .4 SEC DELAY
BOTH SEATS DIVERGE.LEFT
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
40.00
80.00
120.00
160.00
200.00
TIME (SEC)
0.70
1.10
1.50
1.90
2.30
2.70
3.10
A
C
B
D

Figure D-132

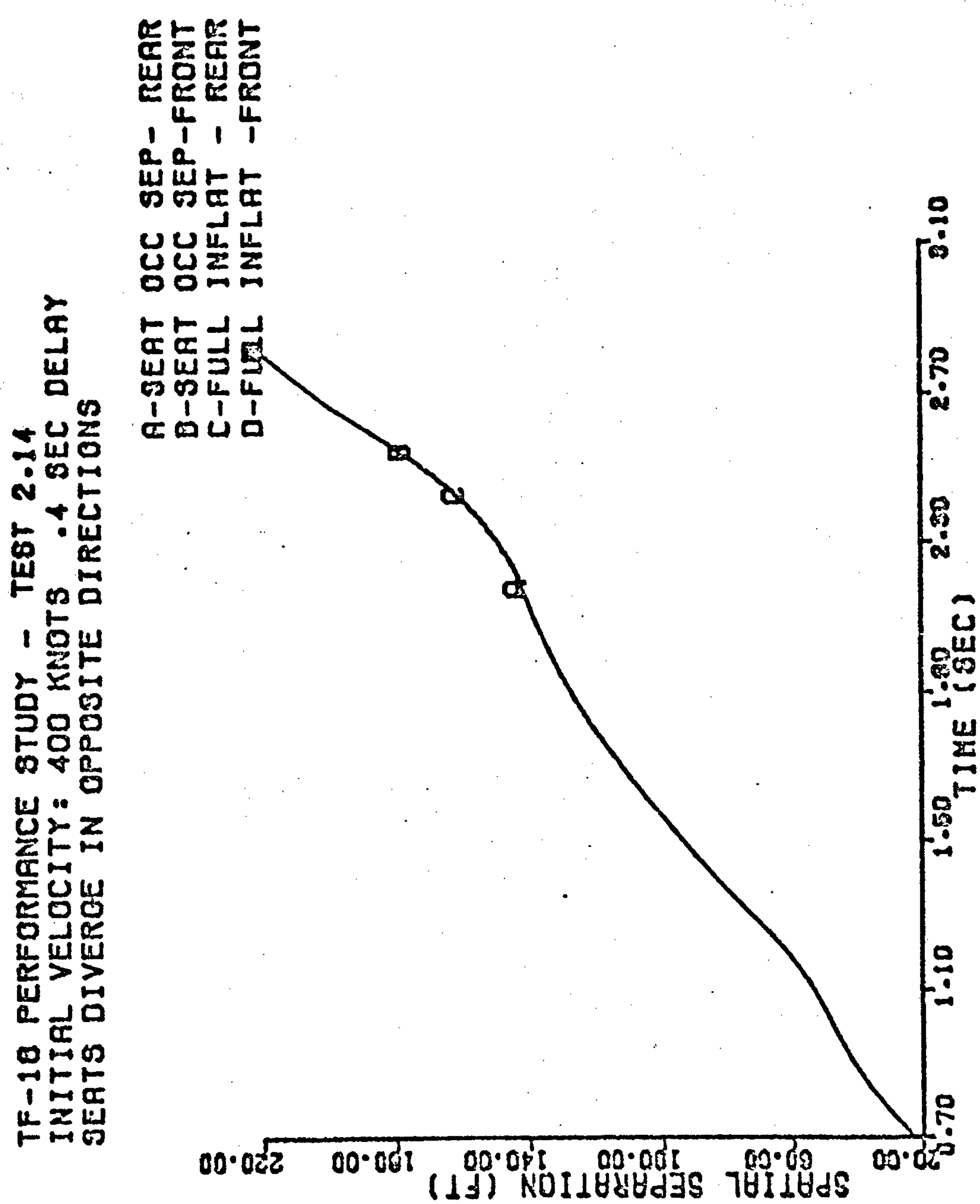

TF-18 PERFORMANCE STUDY - TEST 2.14
INITIAL VELOCITY: 400 KNOTS .4 SEC DELAY
SEATS DIVERGE IN OPPOSITE DIRECTIONS
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
20.00
60.00
100.00
140.00
180.00
220.00
TIME (SEC)
0.70
1.10
1.50
1.90
2.30
2.70
3.10

Figure D-133

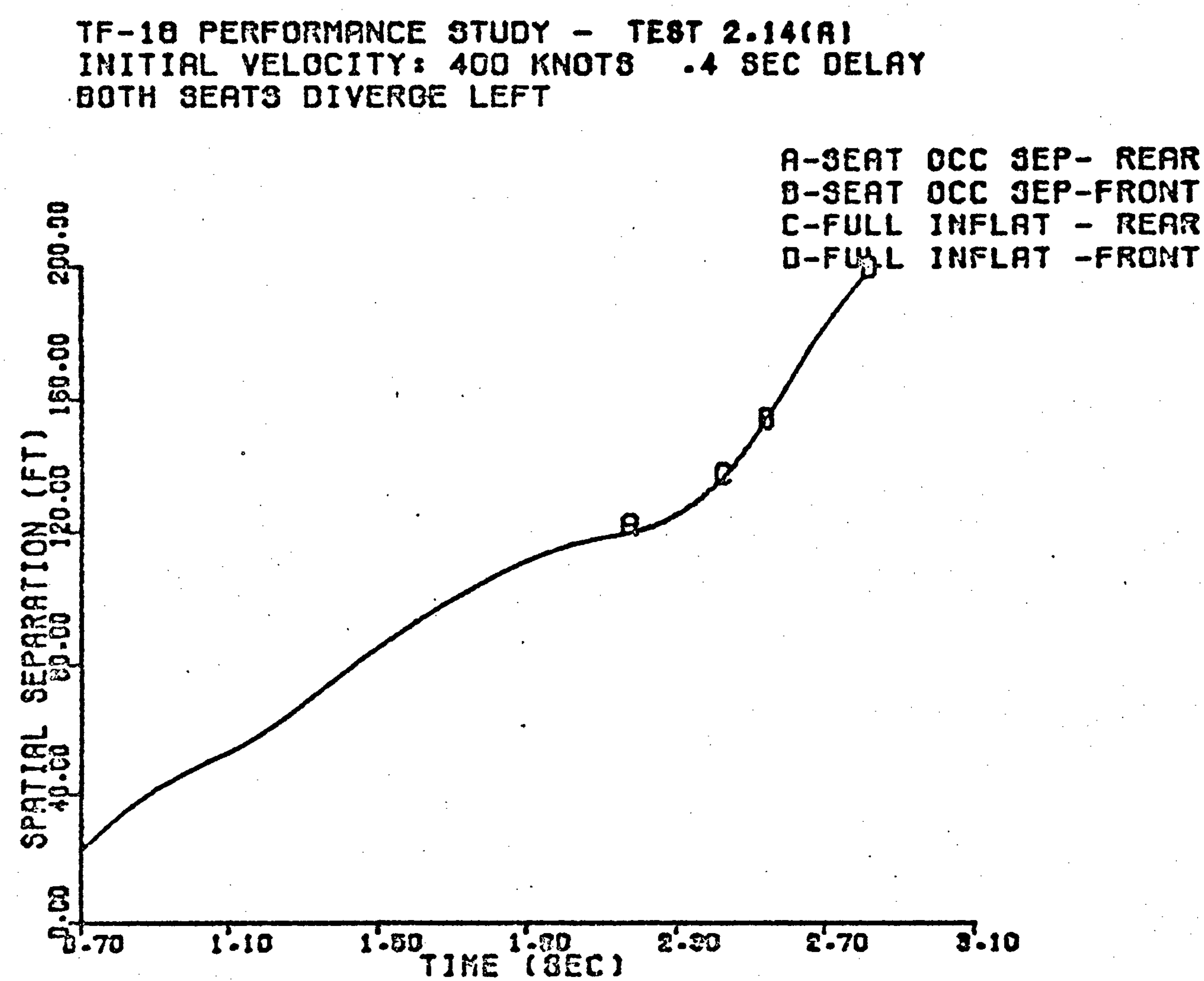

TF-18 PERFORMANCE STUDY - TEST 2.14(A)
INITIAL VELOCITY: 400 KNOTS .4 SEC DELAY
BOTH SEATS DIVERGE LEFT
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
40.00
80.00
120.00
160.00
200.00
0.70
1.10
1.50
1.90
2.30
2.70
3.10
TIME (SEC)

Figure D-134

TF-18 PERFORMANCE STUDY - **TEST 2.16** .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 500 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT

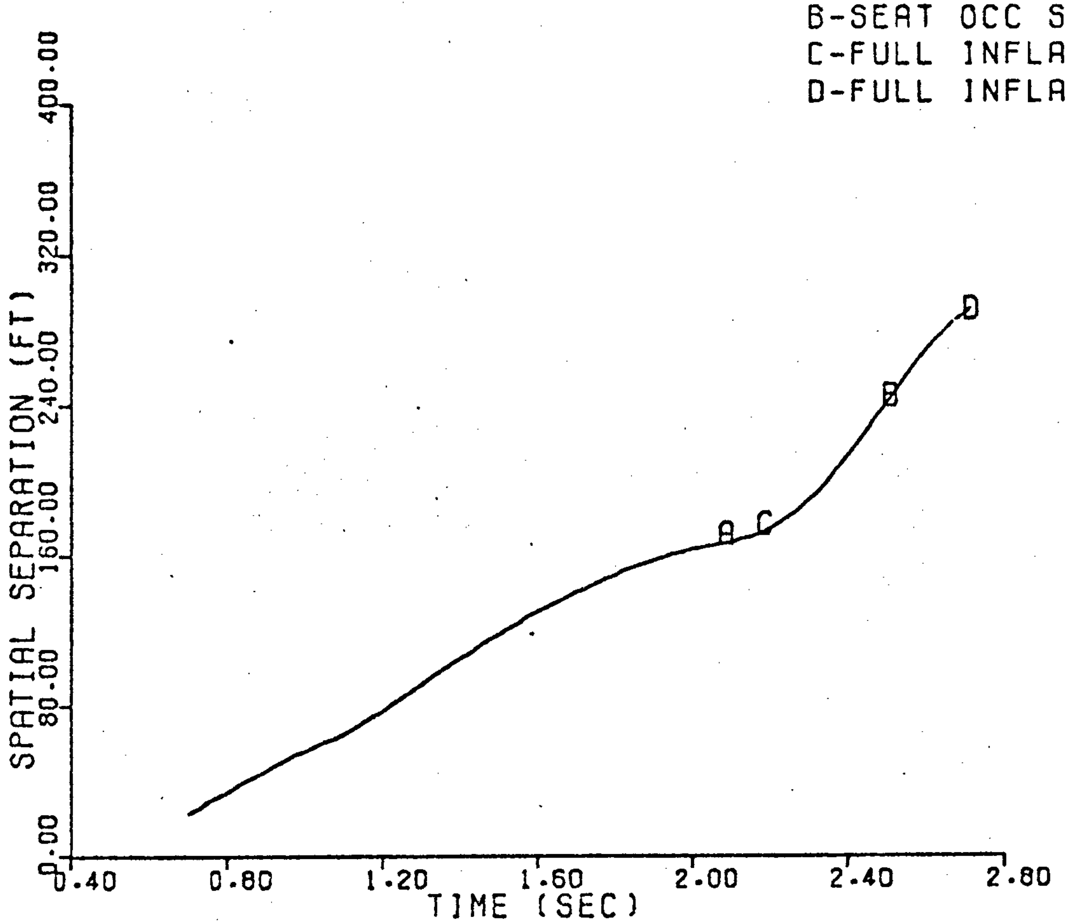


Figure D-135

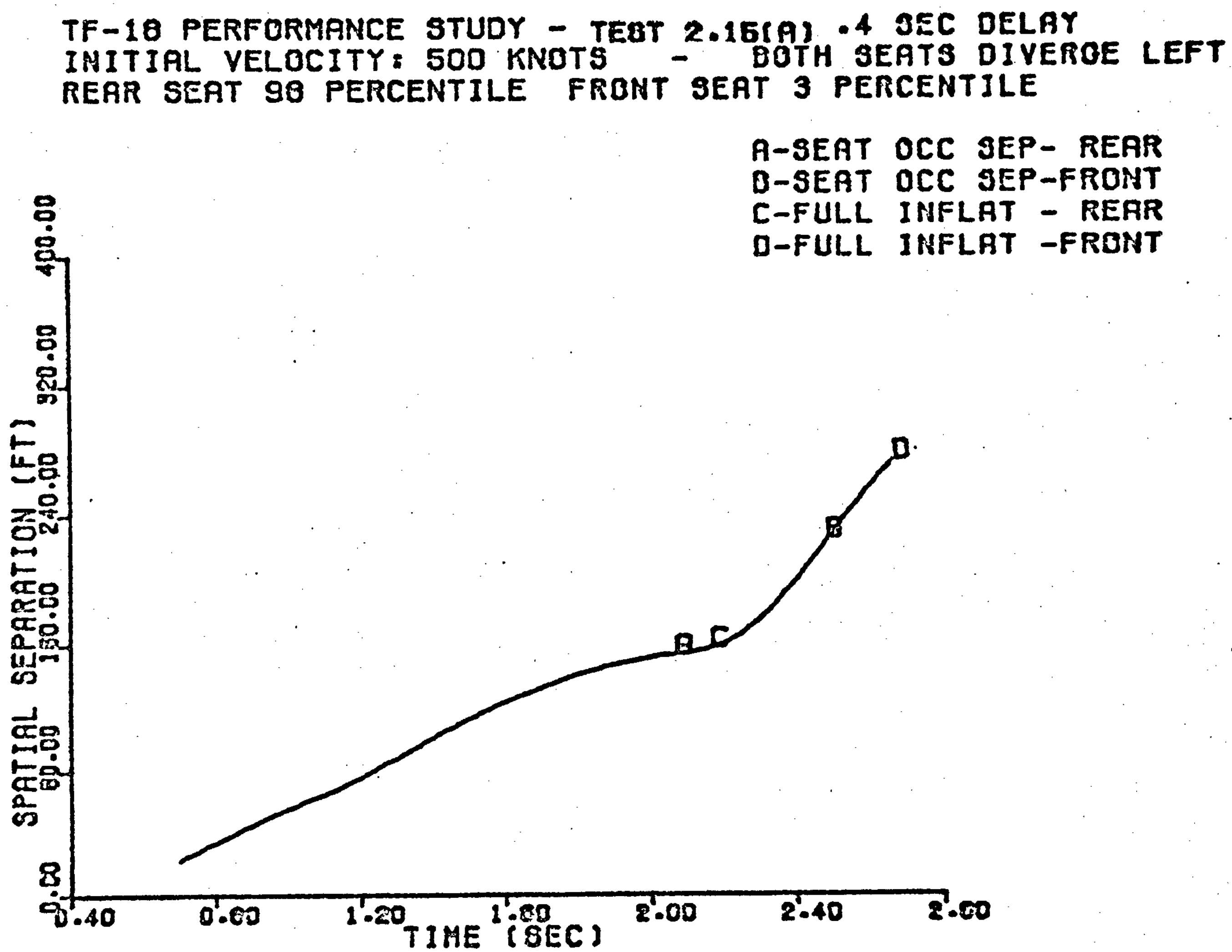

TF-18 PERFORMANCE STUDY - TEST 2.15(A) .4 SEC DELAY
INITIAL VELOCITY: 500 KNOTS - BOTH SEATS DIVERGE LEFT
REAR SEAT 98 PERCENTILE FRONT SEAT 3 PERCENTILE
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
80.00
160.00
240.00
320.00
400.00
TIME (SEC)
0.40
0.80
1.20
1.60
2.00
2.40
2.80
A
C
B
D

Figure D-136

TF-18 PERFORMANCE STUDY - TEST 2.18 .4 SEC DELAY
REAR SEAT 3 PCNTL FRONT SEAT 98 PCNTL VEL: 500 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT

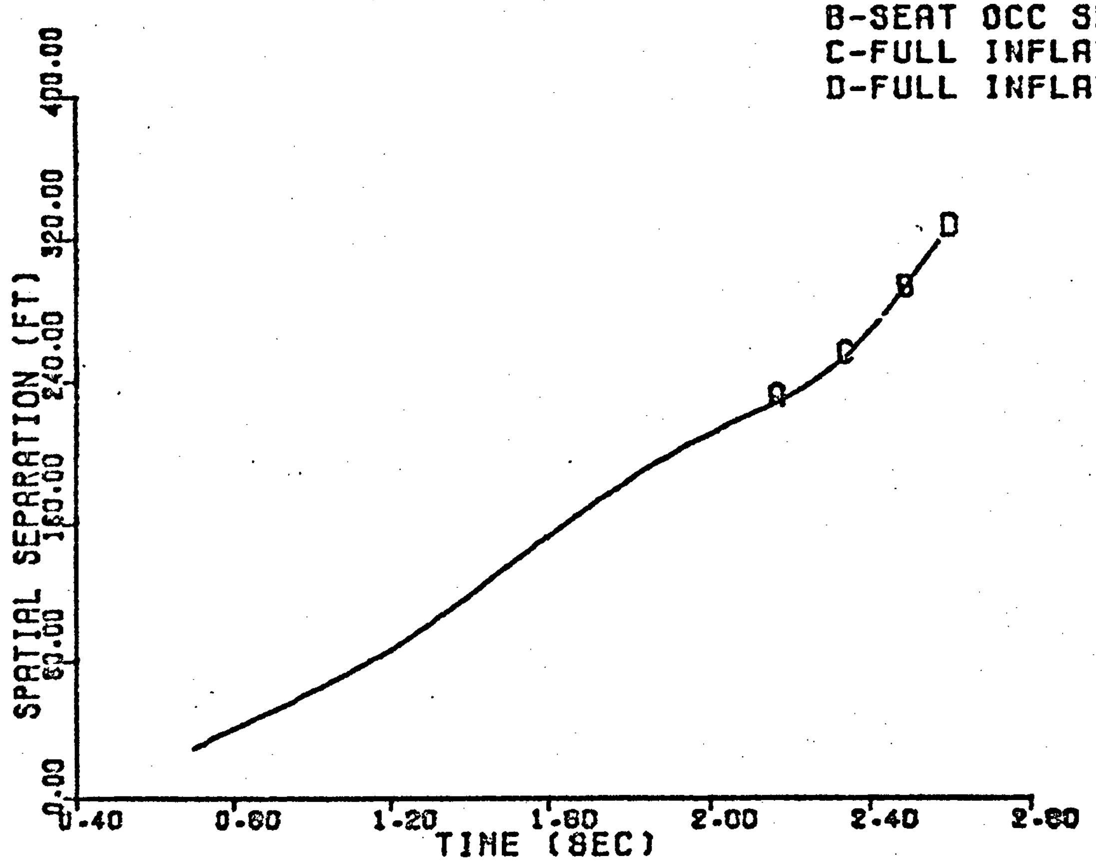


Figure D-137

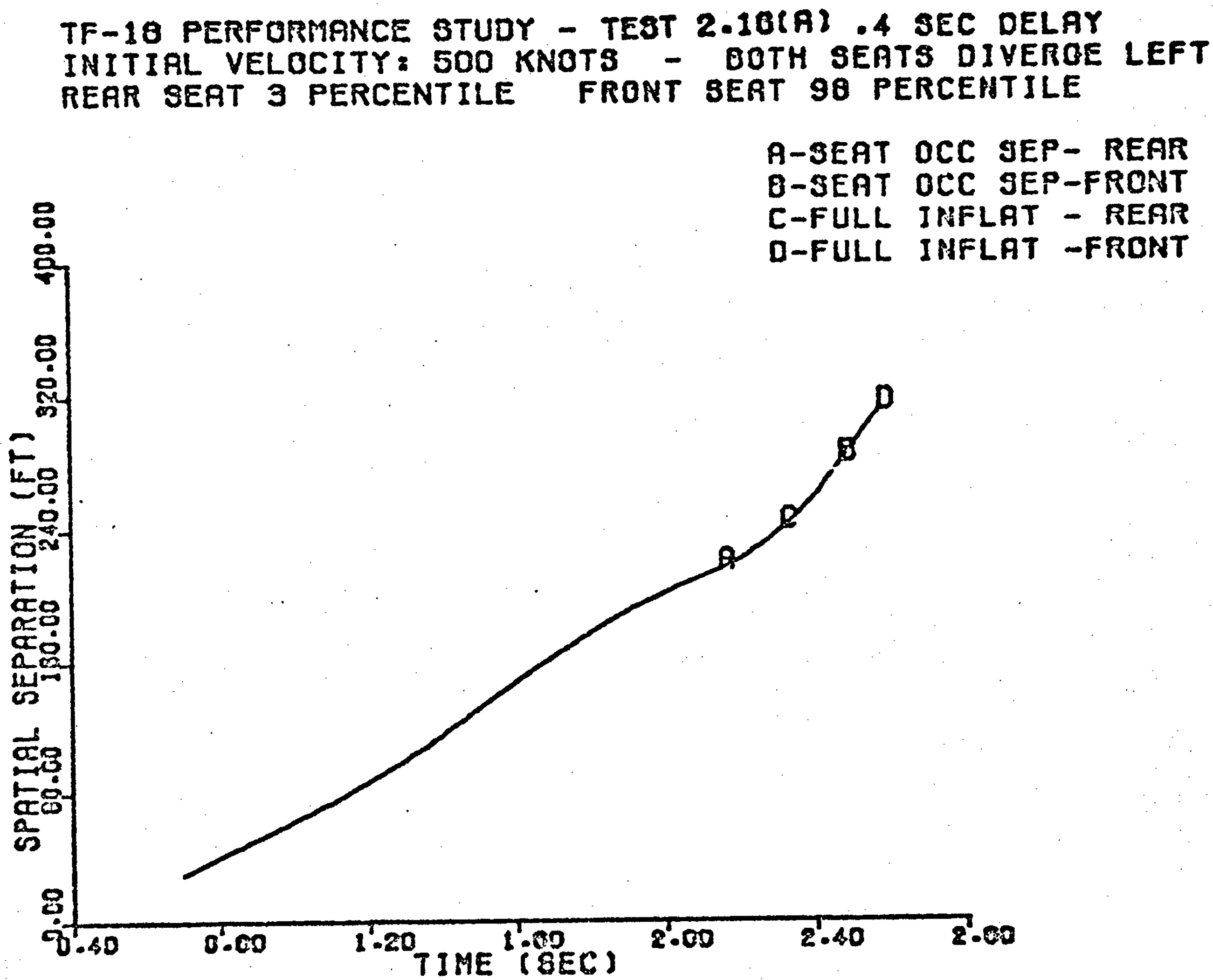

TF-18 PERFORMANCE STUDY - TEST 2.18(A) .4 SEC DELAY
INITIAL VELOCITY: 500 KNOTS - BOTH SEATS DIVERGE LEFT
REAR SEAT 3 PERCENTILE FRONT SEAT 98 PERCENTILE
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
TIME (SEC)
A
B
C
D

Figure D-138

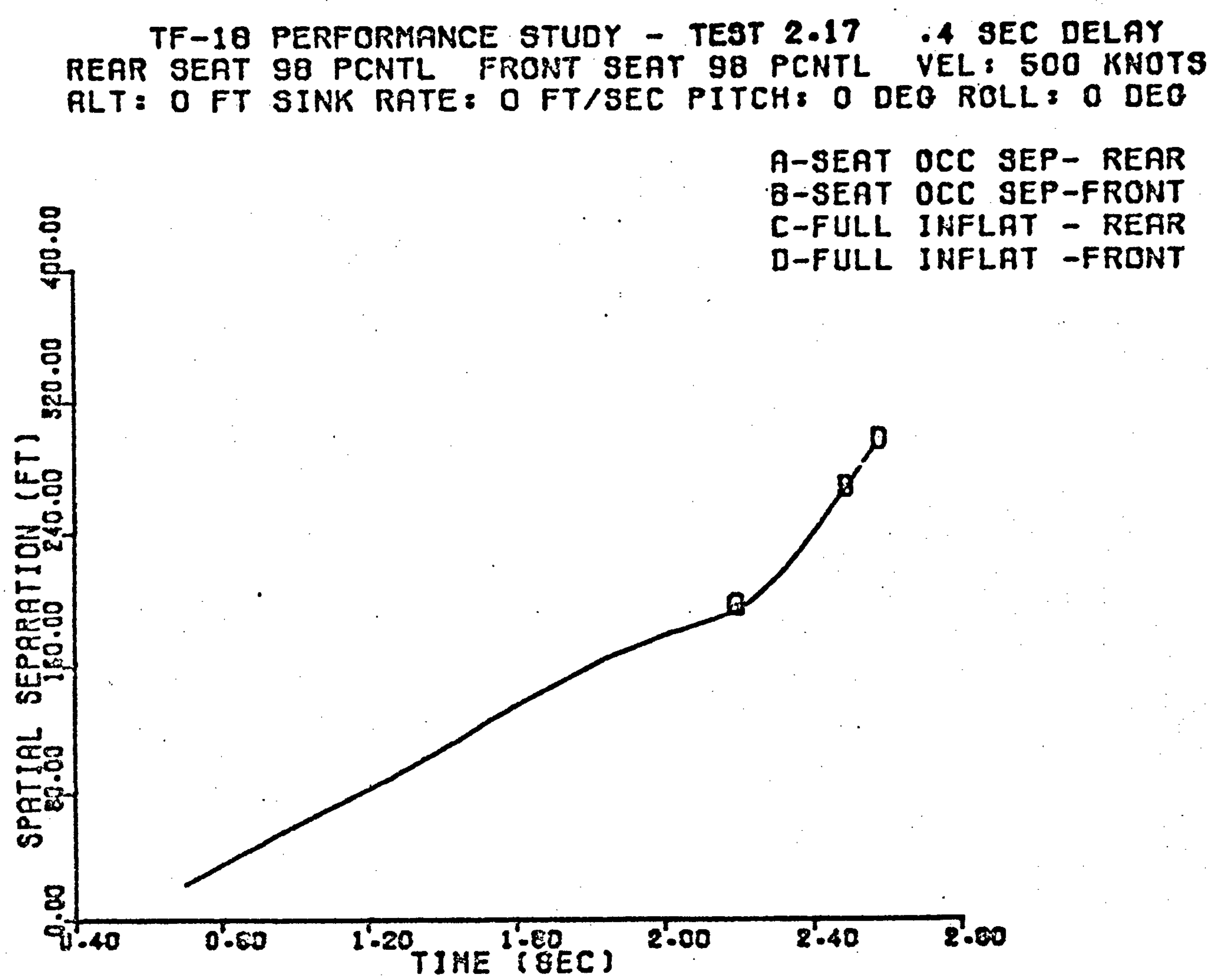

TF-18 PERFORMANCE STUDY - TEST 2.17 .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 98 PCNTL VEL: 500 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
80.00
160.00
240.00
320.00
400.00
0.40
0.80
1.20
1.60
2.00
2.40
2.80
TIME (SEC)
B
D

Figure D-139

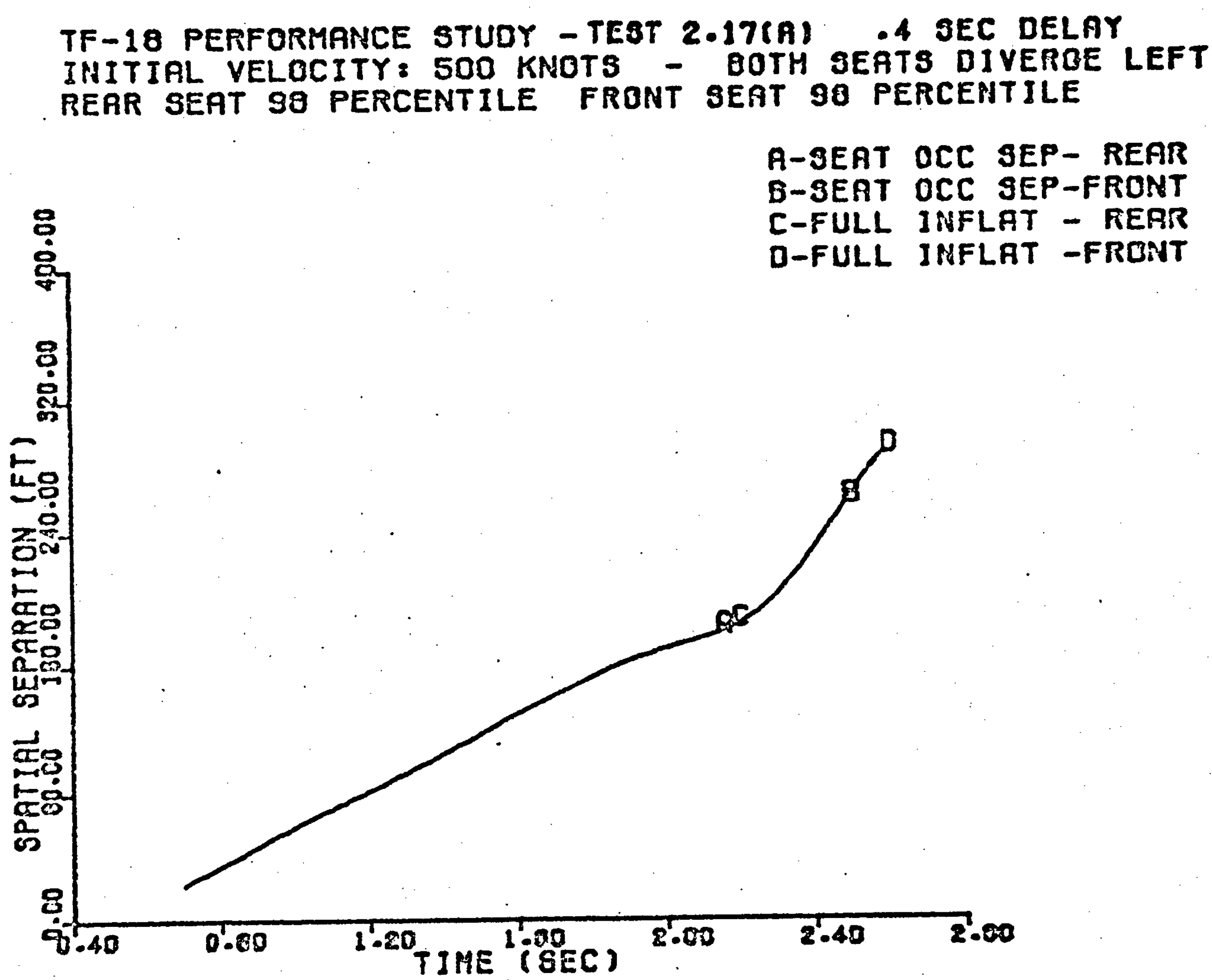

TF-18 PERFORMANCE STUDY - TEST 2.17(A) .4 SEC DELAY
INITIAL VELOCITY: 500 KNOTS - BOTH SEATS DIVERGE LEFT
REAR SEAT 98 PERCENTILE FRONT SEAT 98 PERCENTILE
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
80.00
160.00
240.00
320.00
400.00
0.40
0.80
1.20
1.60
2.00
2.40
2.80
TIME (SEC)

Figure D-140

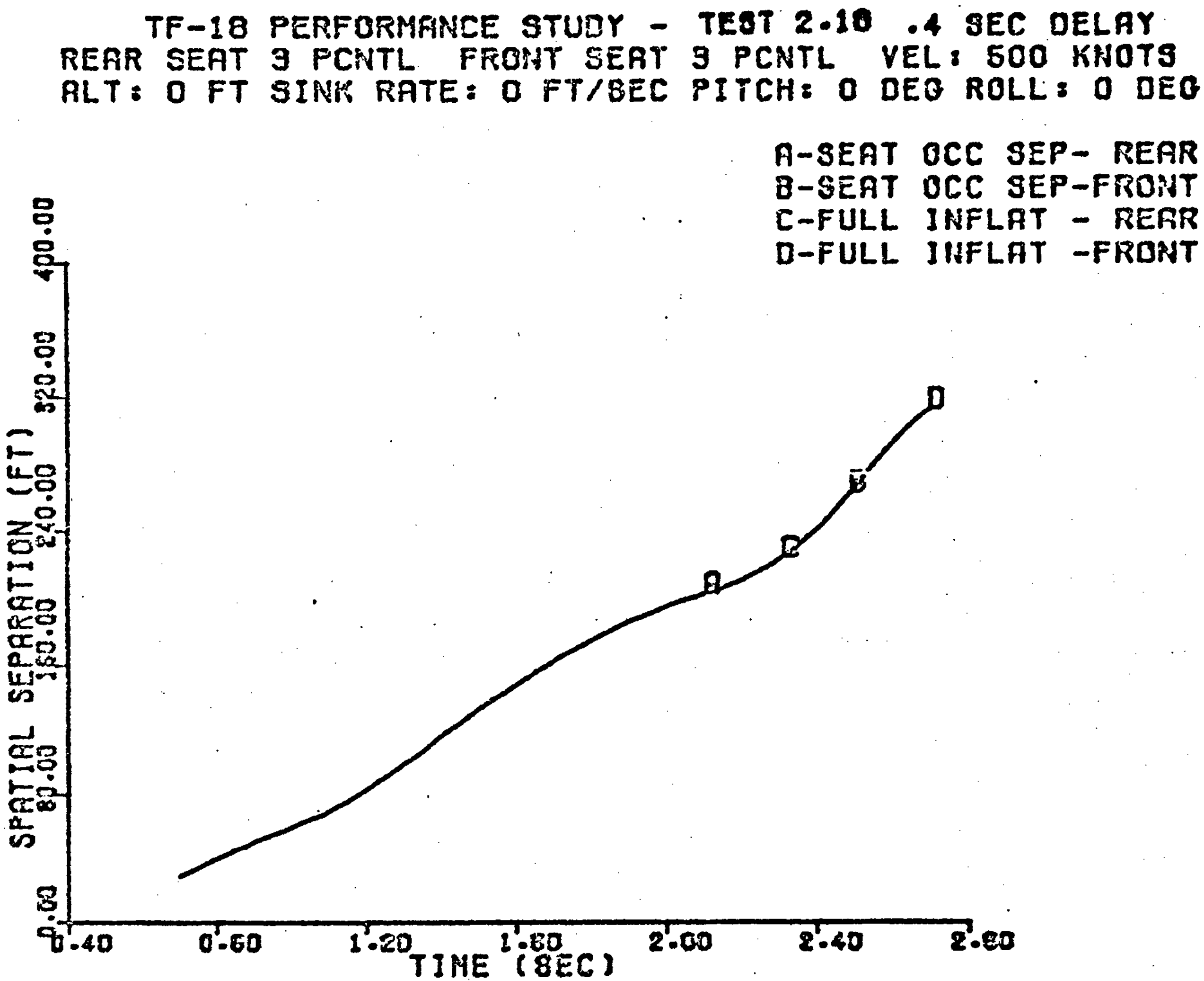

TF-18 PERFORMANCE STUDY - TEST 2.18 .4 SEC DELAY
REAR SEAT 3 PCNTL FRONT SEAT 3 PCNTL VEL: 500 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
80.00
160.00
240.00
320.00
400.00
0.40
0.80
1.20
1.60
2.00
2.40
2.80
TIME (SEC)

Figure D-141

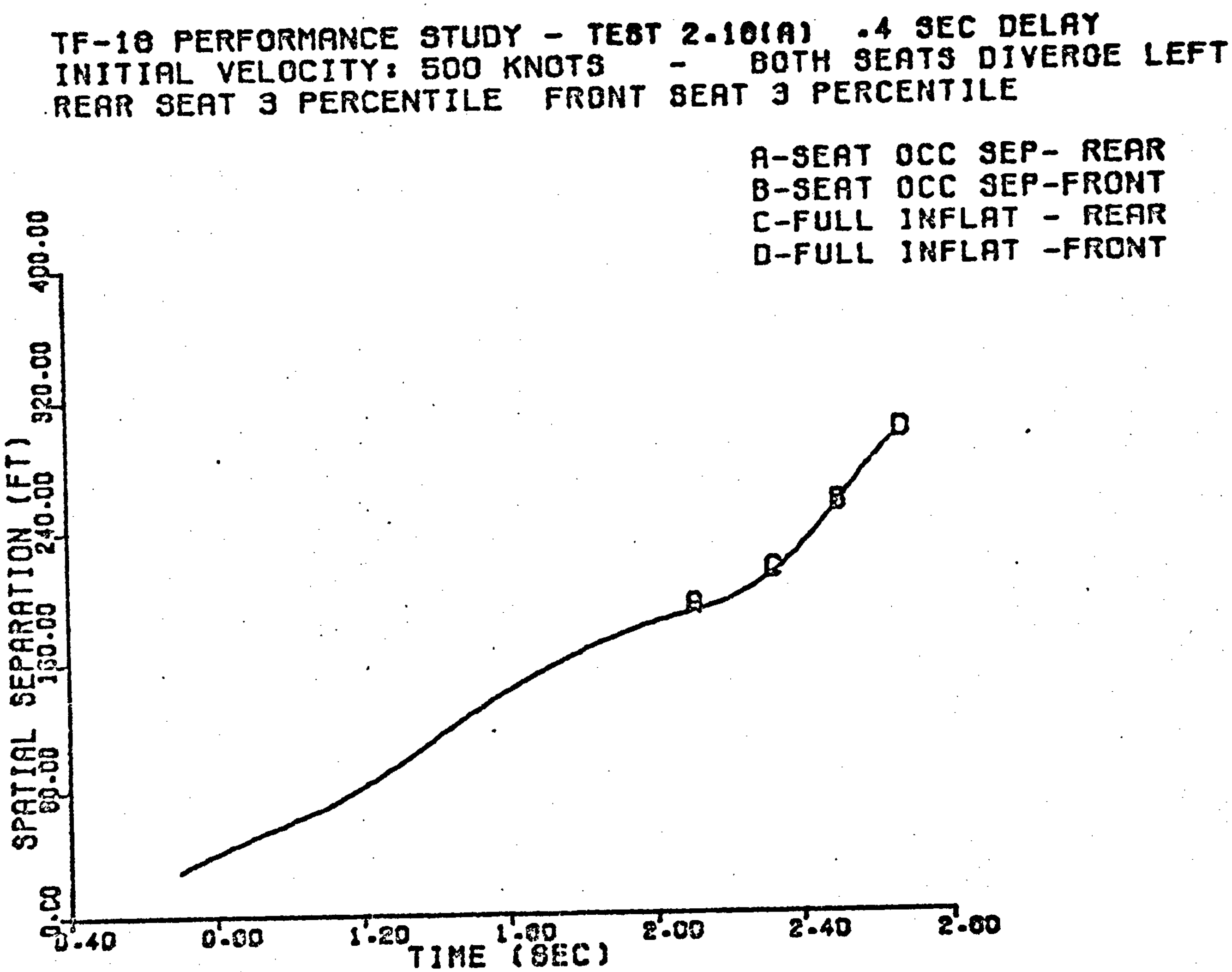

TF-18 PERFORMANCE STUDY - TEST 2.18(A) .4 SEC DELAY
INITIAL VELOCITY: 500 KNOTS - BOTH SEATS DIVERGE LEFT
REAR SEAT 3 PERCENTILE FRONT SEAT 3 PERCENTILE
A-SEAT OCC SEP- REAR
B-SEAT OCC SEP-FRONT
C-FULL INFLAT - REAR
D-FULL INFLAT -FRONT
SPATIAL SEPARATION (FT)
0.00
80.00
160.00
240.00
320.00
400.00
TIME (SEC)
0.40
0.80
1.20
1.60
2.00
2.40
2.80

Figure D-142

TF-18 PERFORMANCE STUDY - .4 SEC DELAY TEST 3.1
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 0 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: -30 DEG ROLL: -30 DEG

○ REAR SEAT
△ FRONT SEAT

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

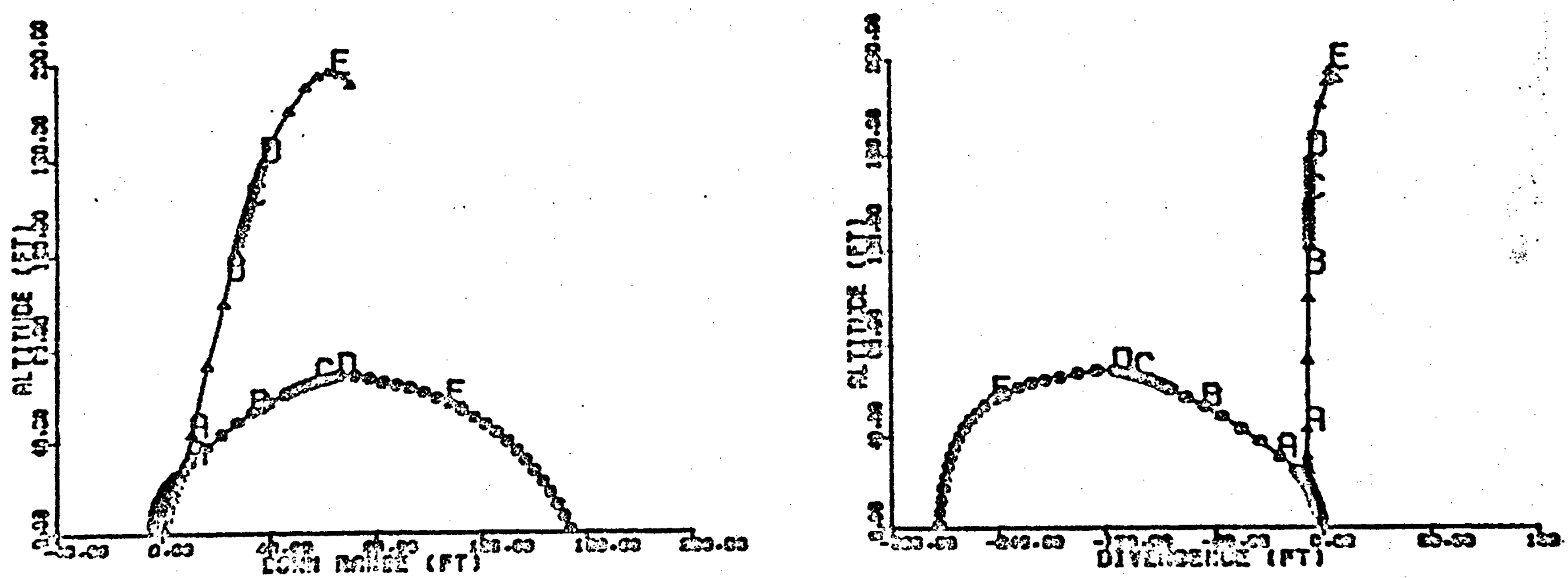


Figure D-143

TF-18 PERFORMANCE STUDY - .4 SEC DELAY TEST 3.1(A)
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 0 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: -30 DEG ROLL: - 30 DEG

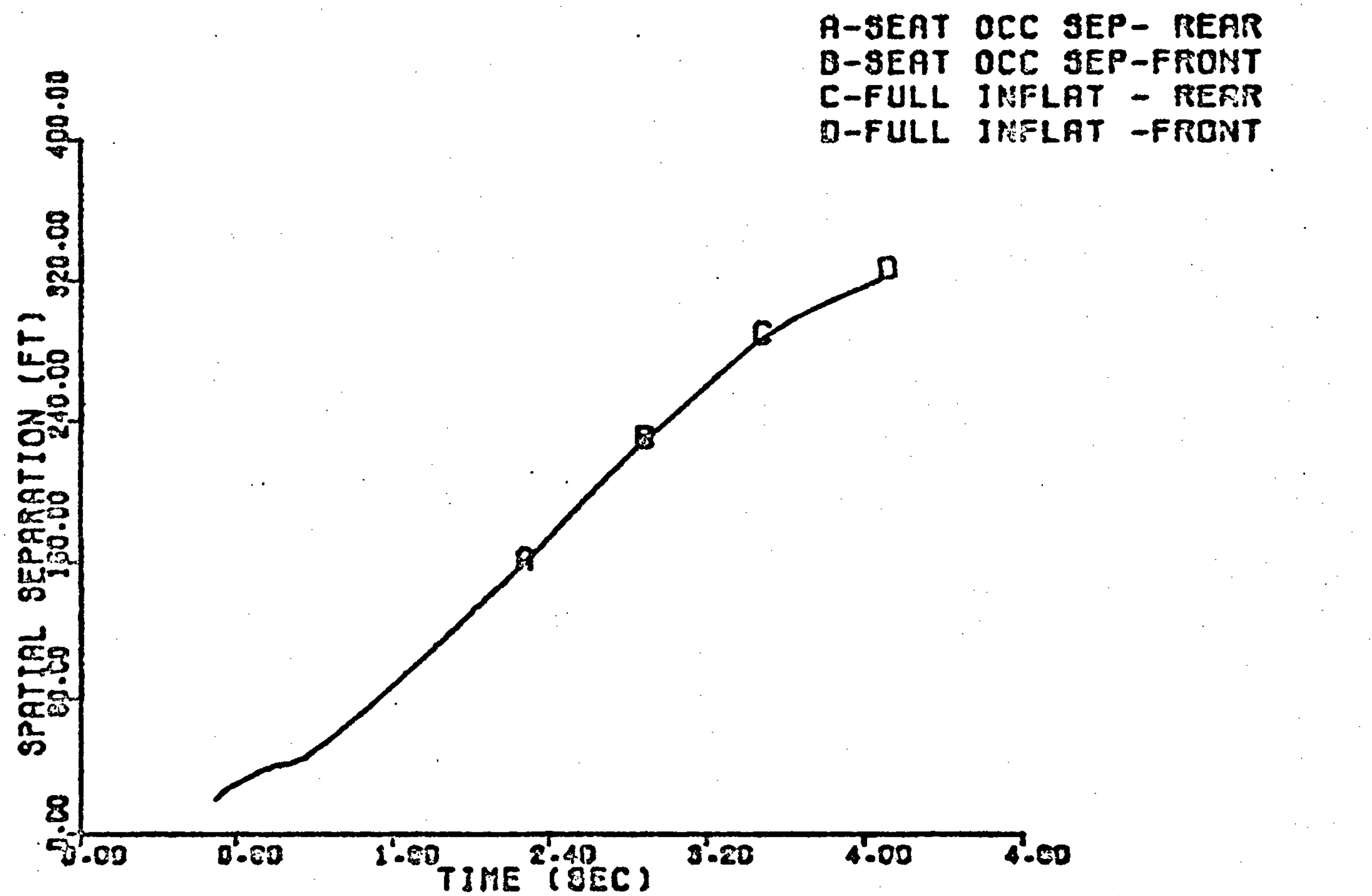


Figure D-144

TF-10 PERFORMANCE STUDY - .4 SEC DELAY TEST 3.2
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 0 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: -30 DEG ROLL: 30 DEG

O REAR SEAT
Δ FRONT SEAT

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION

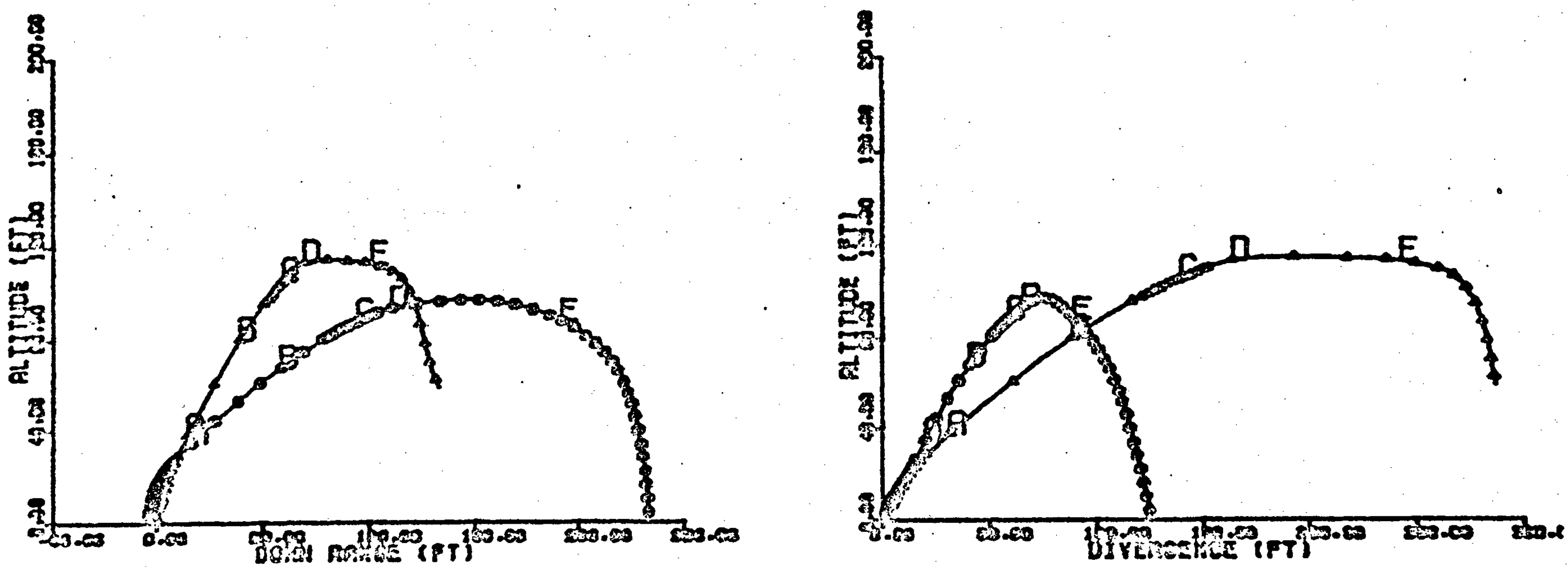


Figure D-145

TF-18 PERFORMANCE STUDY - .4 SEC DELAY   TEST 3.2(A)
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 0 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: -30 DEG ROLL: 30 DEG

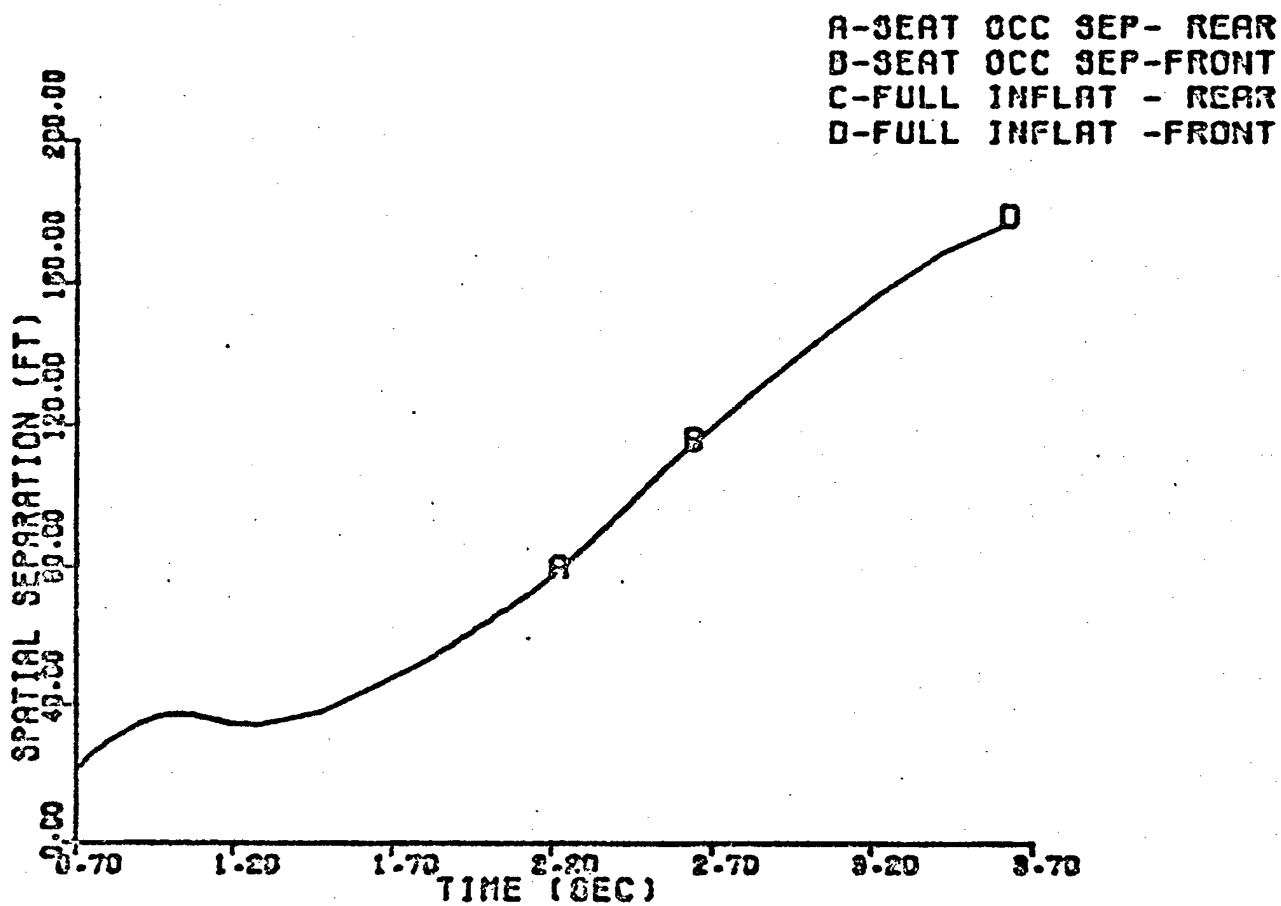
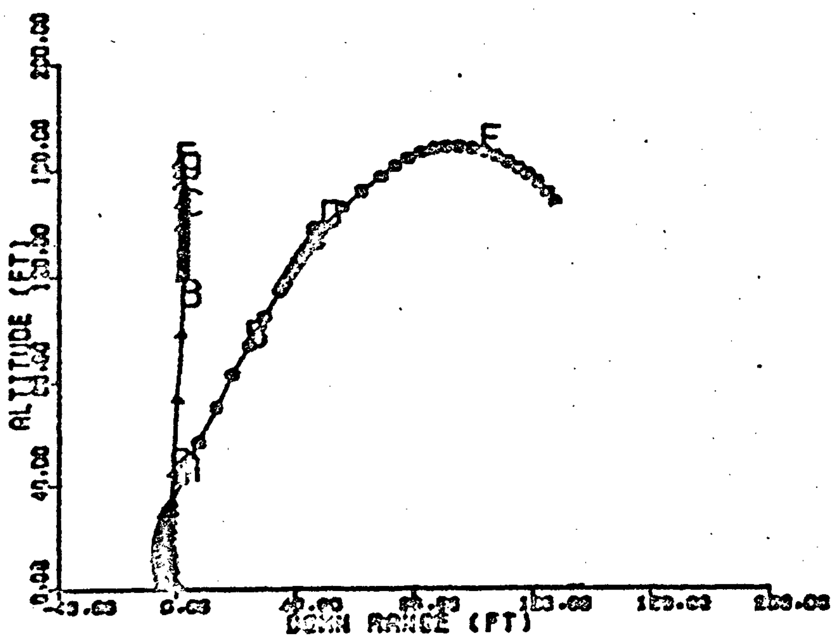


Figure D-146

TF-18 PERFORMANCE STUDY - .4 SEC DELAY TEST 4.1
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 0 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: -10 DEG ROLL: 20 DEG

○ REAR SEAT
△ FRONT SEAT

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION



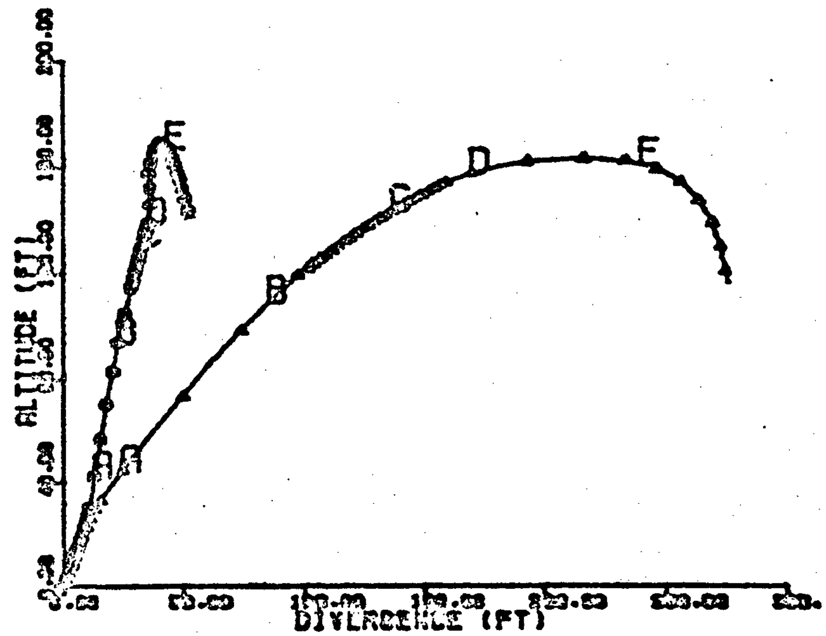
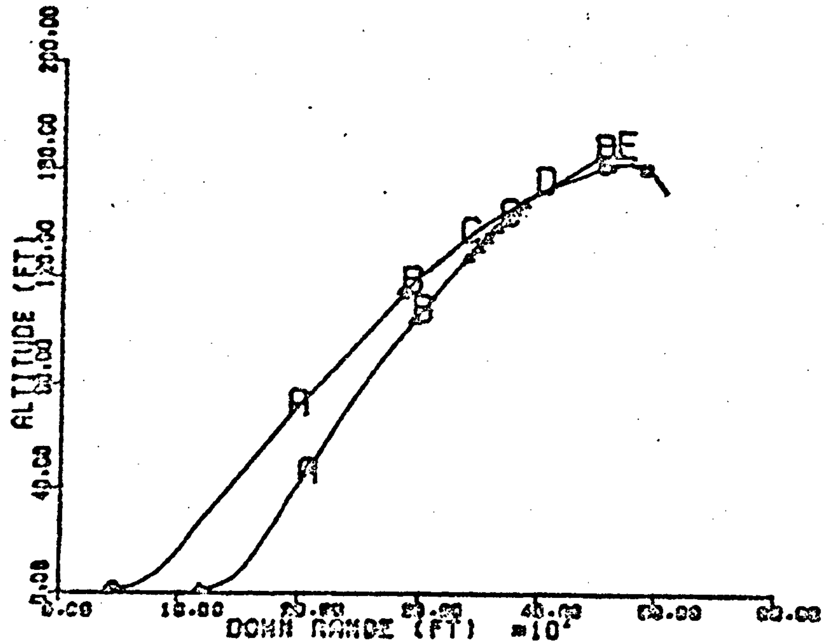


Figure D-147

TF-18 PERFORMANCE STUDY - .4 SEC DELAY TEST 4.2
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 100 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 D EG

O REAR SEAT
△ FRONT SEAT

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION



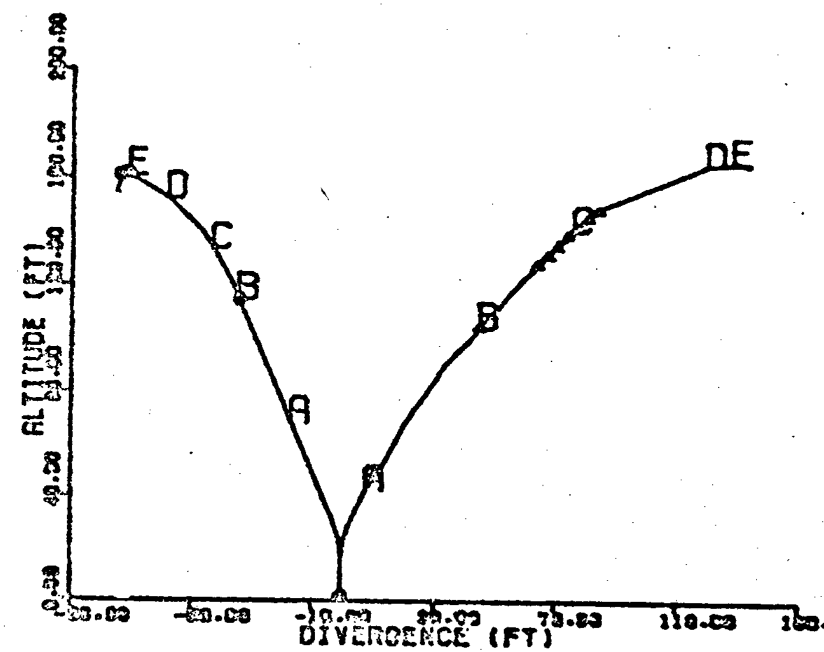


Figure D-148

TF-18 PERFORMANCE STUDY - .4 SEC DELAY TEST 4.3
REAR SEAT 98 PCNTL FRONT SEAT 3 PCNTL VEL: 150 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

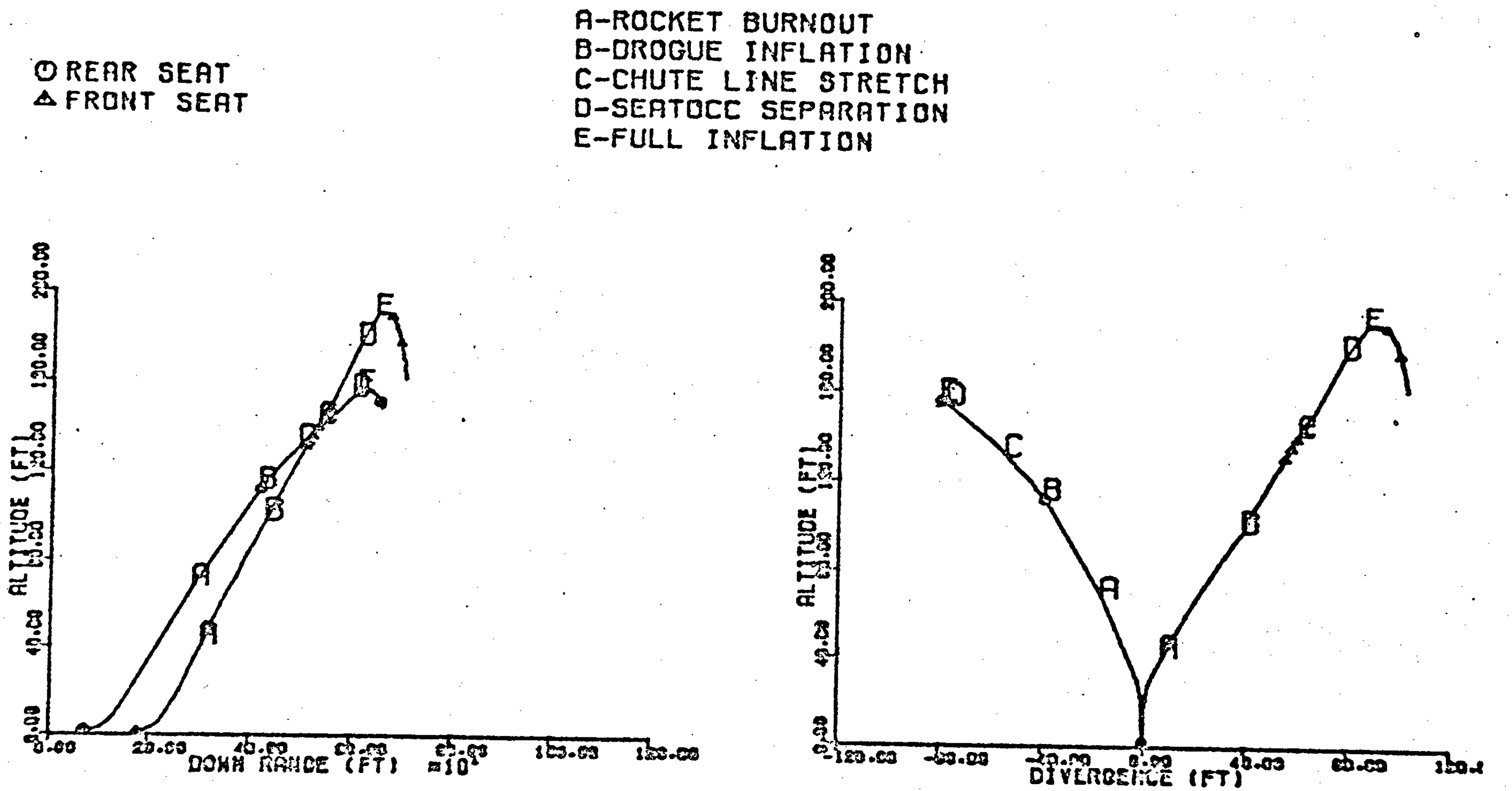
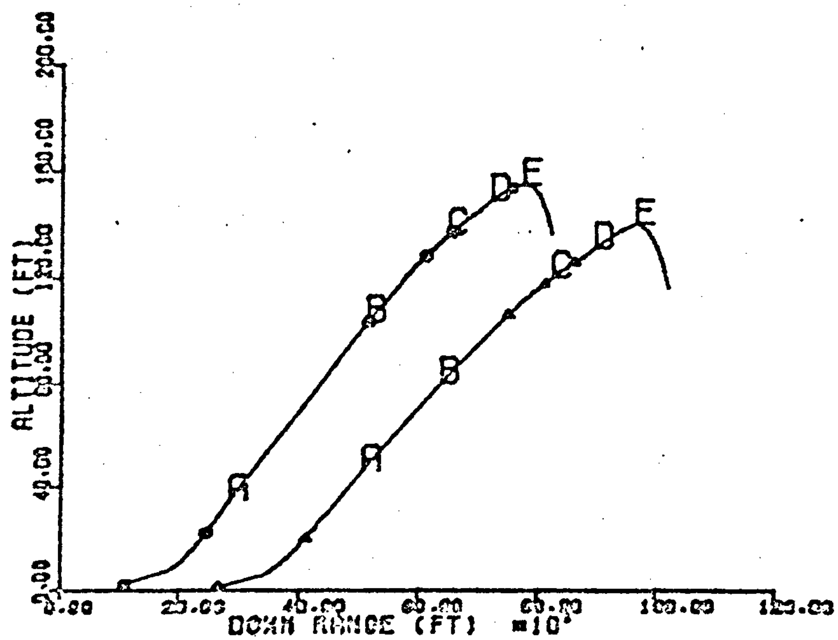


Figure D-149

TF-18 PERFORMANCE STUDY - .4 SEC DELAY TEST 4.4
REAR SEAT 3 PCNTL FRONT SEAT 98 PCNTL VEL: 225 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

○ REAR SEAT
△ FRONT SEAT

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION



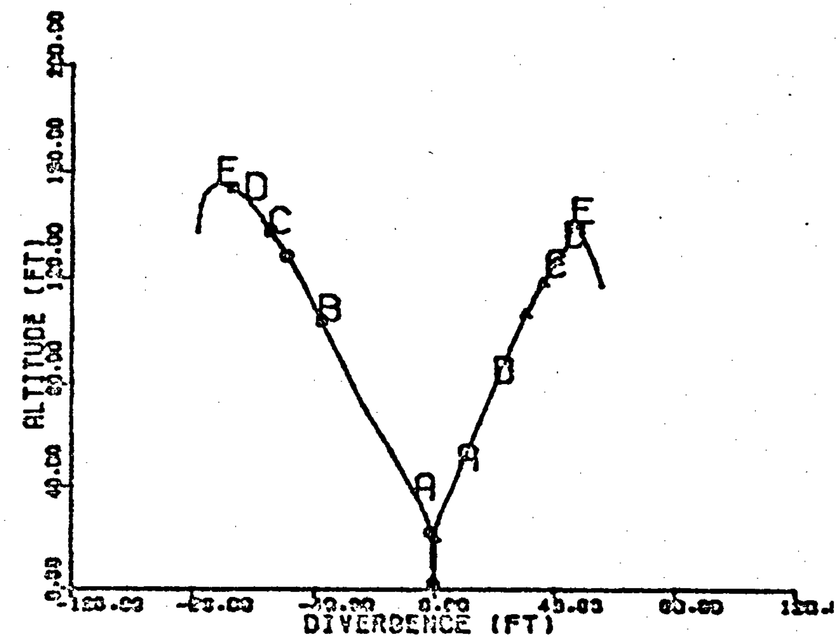
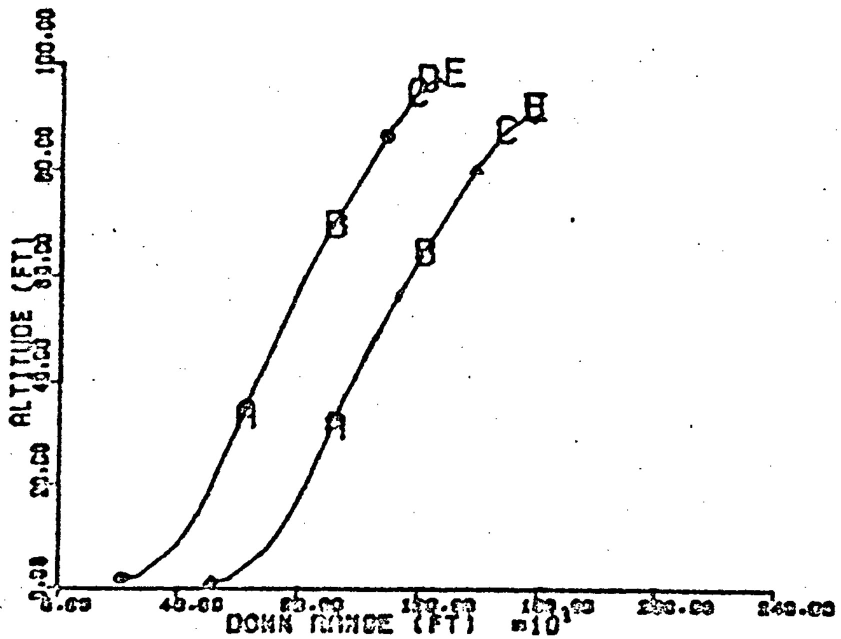


Figure D-150

TF-18 PERFORMANCE STUDY - .4 SEC DELAY TEST 4.5
REAR SEAT 3 PCNTL FRONT SEAT 98 PCNTL VEL: 435 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

○ REAR SEAT
△ FRONT SEAT

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATOCC SEPARATION
E-FULL INFLATION



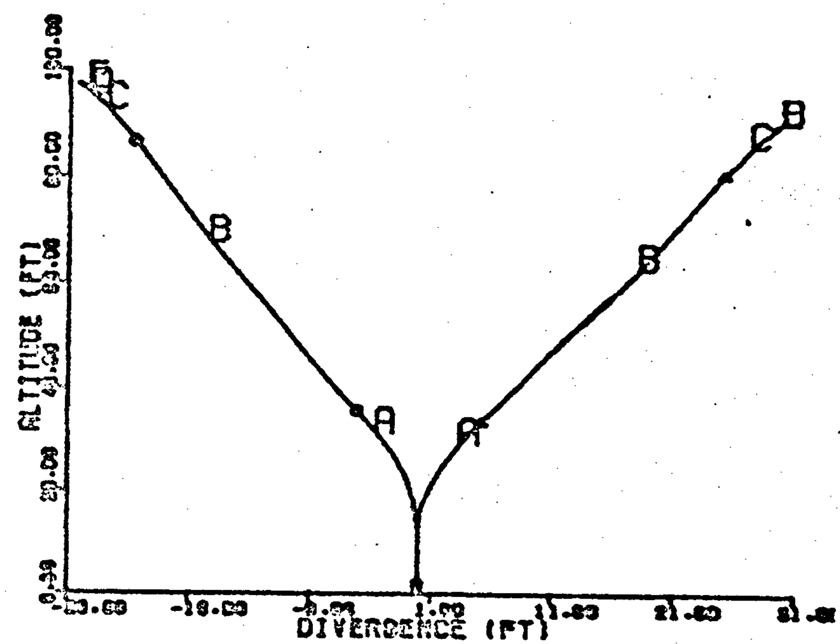


Figure D-151

TEST 4.8

TF-18 PERFORMANCE STUDY - .4 SEC DELAY
REAR SEAT 98 PCNTL FRONT SEAT 99 PCNTL VEL: 600 KNOTS
ALT: 0 FT SINK RATE: 0 FT/SEC PITCH: 0 DEG ROLL: 0 DEG

O REAR SEAT
△ FRONT SEAT

A-ROCKET BURNOUT
B-DROGUE INFLATION
C-CHUTE LINE STRETCH
D-SEATDCC SEPARATION
E-FULL INFLATION

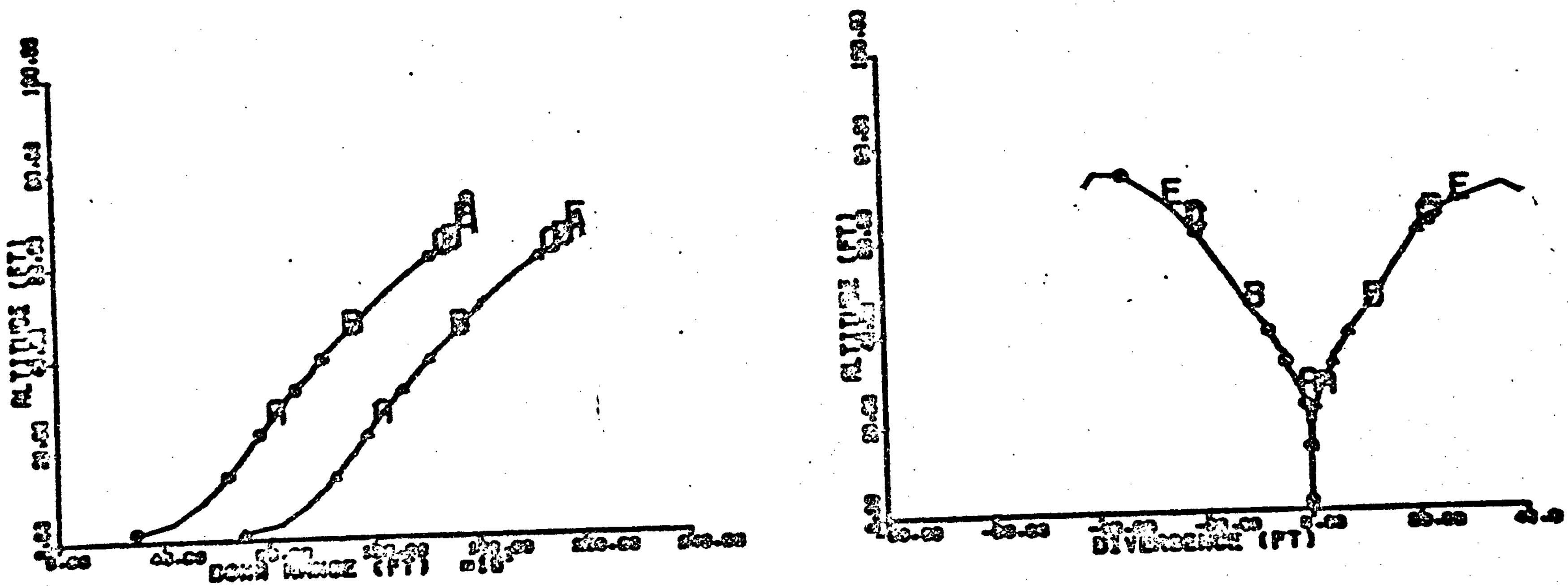


Figure D-152